KEITHLEY

Instruction Manual

Model 177

Contains Operating and Servicing/Calibration Information for Models 177 and 1788.

Keithley Instruments, Inc.
28775 Aurora Road/Cleveland, Ohio 44139/(216) 248-0400

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay local domestic surface freight costs.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and shipping instructions.

REPAIRS AND CALIBRATION

Keithley Instruments maintains a complete repair and calibration service as well as a standards laboratory in Cleveland, Ohio.

A Keithley service facility at our Munich, Germany office is available for our customers throughout Europe. Service in the United Kingdom can be handled at our office in Reading. Additionally, Keithley representatives in most countries maintain service and calibration facilities.

To insure prompt repair or recalibration service, please contact your local field representative or Keithley headquarters directly before returning the instrument. Estimates for repairs, normal recalibrations and calibrations traceable to the National Bureau of Standards are available upon request.

KEITHLEY
The measurement engineers.

Keithley Instruments, Inc., 28775 Aurora Road, Cleveland, Ohio 44139. (216) 248-0400

European Headquarters: Heiglhofstrasse 5, D-8000 Munchen 70 West Germany, (089) 7144065
United Kingdom: 1 Boulton Road, Reading, Berkshire, (0734) 861287
France: 44 Rue Anatole France, F-91121 Palaiseau (01) 014-22-06

INSTRUCTION MANUAL

Microvolt Digital Multimeter

Model 177

COPYRIGHT 1978, KEITHLEY INSTRUMENTS, INC.

FIRST PRINTING, DEC. 1978, CLEVELAND, OHIO U. S. A.

DOCUMENT NO. 29683

CONTENTS

Section	Page
CONTENTS.	
ILLUSTRATIONS	
1. GENERAL INFORMATION	1-1
1-1. INTRODUCTION	1-1
1-2. WARRANTY INFORMATION.	1-1
1-3. CHANGE NOTICE	1-1
SPECIFICATIONS	1-2
2. OPERATION	2-1
2-1. GENERAL	2-1
2-2. INSPECTION	2-1
2-3. PREPARATION FOR USE	2-1
2-4. OPERATION ON LINE POWER	2-1
2-5. OPERATION ON BATTERY PACK POWER	2-1
2-6. BATTERY CHARGING	2-1
2-7. OPERATING INSTRUCTIONS.	2-5
2-8. ZERO ADJUSTMENTS	2-6
2-9. DC VOLTAGE MEASUREMENT.	2-6
2-10. AC VOLTAGE MEASUREMENT	2-8
2-11. RESISTANCE (Ω) MEASUREMENT.	2-9
2-12. DC CURRENT MEASUREMENT	2-11
2-13. AC CURRENT MEASUREMENT.	2-11
2-14. TRMS MEASUREMENT (AC & DC)	2-12
2-15. ANALOG OUTPUT	2-12
3. PERFORMANCE VERIFICATION	3-1
3-1. GENERAL	3-1
3-2. RECOMMENDED TEST EQUIPMENT	3-1
3-3. ENVIORNMENTAL CONDITIONS.	3-1
3-4. PERFORMANCE VERIFICATION PROCEDURE	3-1
4. ACCESSORIES	4-1
4-1. GENERAL	4-1
4-2. POWER OPTIONS	4-1
4-3. CONVENIENCE CABLES & CONNECTORS	4-1
4-4. PROBES & SHUNTS	4-2
4-5. CARRYING CASE & RACK MOUNTS	4-4
5. OPERATING INSTRUCTIONS.	5-1
5-1. GENERAL	5-1
5-2. OVERALL OPERATION	5-2
5-3. AC CONVERTER	5-3
5-4. DC SIGNAL CONDITIONING.	5-4
5-5 OHMS CONVERSION	5-6
5-6. ANALOG OUTPUT	5-7
5-7. CLOCK	5-7
5-8. A/D CONVERTER	5-8
5-9. DISPLAY	5-8
5-10. AC POWER SUPPLY	5-8
5-11. MODEL 1788 BATTERY PACK	5-8
6. MAINTENANCE	6-1
6-1. GENERAL	6-1

CONTENTS (CON'T)

Section		Page
6-2.	RECOMMENDED TEST EQUIPMENT	6-1
6-3.	ENVIRONMENTAL CONDITIONS	6-1
6-4.	CALIBRATION PROCEDURE	6-1
6-5.	TROUBLESHOOTING	6-5
6-6.	TROUBLESHOOTING PROCEDURE	6-5
6-7.	FRONT PANEL ZERO KNOB REMOVAL AND REPLACEMENT	6-15
6-8.	FUSE REPLACEMENT	6-16
7.	REPLACEABLE PARTS	7-1
7-1.	GENERAL	7-1
7-2.	ORDERING INFORMATION	7-1
7-3.	FACTORY SERVICE	7-1
7-4.	SCHEMATICS	7-1
7-5.	COMPONENT LAYOUT	7-1
7-6.	MAINTENANCE KIT	7-1

Illustrations

Figure No.	Illustrations	Page
1-1.	Model 177 Front Panel	1-1
1-2.	Dimensional Data	1-3
1-3.	Tilt Bail Positions	1-4
2-1.	Rear View of Standard Line Voltage Instruments	2-2
2-2	Rear View of Optional Line Voltage Instruments	2-2
2-3.	Battery Pack Installation	2-3
2-4.	Operational Controls	2-6
3-1.	Test Circuit For 20mV DC Accuracy Check	3-3
4-1.	Convenience Cables and Connectors	4-1
4-2.	Model 1600 High Voltage Probe & Model 1651 50-Ampere Shunt	4-3
4-3.	Model 1682 RF Probe and Model 1685 Clamp-On AC Current Probe	4-3
4-4.	Carrying Case and Rack Mounting Kits	4-4
5-1.	Simplified Signal Flow Block Diagram, Model 177 DMM	5-1
5-2.	Simplified Signal Conditioning	5-5
5-3.	A/D Converter Function (Sheet 1)	5-9
5-3.	A/D Converter Function (Sheet 2)	5-10
6-1.	Test Point Locations	6-3
6-2.	Integrator and Comparator Waveforms	6-9
6-3.	Front Panel Zero Knob Removal	6-15
7-1.	Covers and Panels	7-3

SECTION 1. GENERAL INFORMATION

1-1. INTRODUCTION. The Model 177 Microvolt DMM is a versatile digital multimeter useful for measurement of ac and dc voltage, ac and dc current and resistance. Ranges and accuracies are listed in the Table of Specifications on Page 1-2. The instrument features include (a) 20,000 count accuracy with a 4-1/2 digit display; (b) resolution of 1μV/digit and 1mΩ/digit; (c) front panel zero compensation for lead resistance and thermal EMF's; (d) automatic indication of polarity; (e) and an Analog Output. Ranges and functions are selected with pushbuttons on the front of the instrument. The decimal point is properly positioned as the range is selected.

1-2. WARRANTY INFORMATION. The Warranty is given on the inside front cover of this Instruction Manual. If there is a need to exercise the Warranty, contact the Keithley Representative in your area to determine the proper action to be taken. Keithley maintains service facilities in the United Kingdom and West Germany, as well as in the United States. Check the inside front cover of the Instruction Manual for addresses.

1-3. CHANGE NOTICES. Improvements or changes to the instrument which occur after printing of the Instruction Manual will be explained on a Change Notice sheet attached to the inside back cover.

IMPORTANT

The ⚠ symbol can be found in various places in this Instruction Manual. Carefully read the associated CAUTION statements with regard to proper use and handling of the instrument. Damage to the instrument may occur if these precautions are ignored.

This ↯ symbol can be found in various places in this Instruction Manual. This symbol indicates those areas on the instrument which are potential shock hazards. Carefully read the associated WARNING statements with regard to proper use and handling of the instrument. Serious personal injury may result if these precautions are ignored.

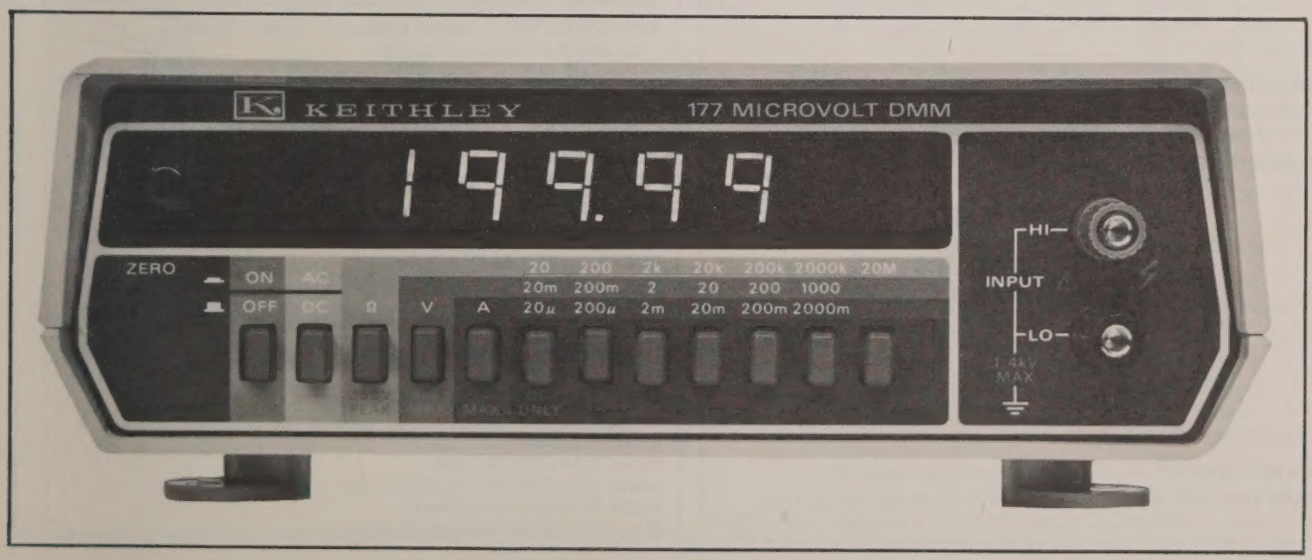


FIGURE 1-1. Model 177 Front Panel.

TABLE 1-1

SPECIFICATIONS, MODEL 177

DC VOLTAGE

RANGE	MAXIMUM READING	ACCURACY (12 months) 18 –28 C (% rdg + digits)	MAXIMUM ALLOWABLE INPUT
20mV*	19.999	0.04 % · 2d	1200V momentary
200mV*	199.99	0.04 % · 1d	1200V momentary
2 V	1.9999	0.03 % · 1d	1200V momentary
20 V	19.999	0.03 % · 1d	1200V
200 V	199.99	0.03 % · 1d	1200V
1200 V	1200.0	0.035% · 1d	1200V

*Front panel zero

TEMPERATURE COEFFICIENT (0 – 18 C and 28 – 55 C): ±(0.005% + 0.1 digit)/ C except ±(0.005% + 0.6 digit)/ C on the 20mV range.

INPUT RESISTANCE: 10MΩ ±0.5%.

NORMAL MODE REJECTION RATIO: Greater than 80dB on the 20mV range at 50Hz and 60Hz; greater than 60dB on all other ranges.

COMMON MODE REJECTION RATIO (1kΩ unbalance): Greater than 120dB at DC, 50Hz and 60Hz.

RESISTANCE

RANGE	MAXIMUM READING	ACCURACY (12 months) 18 –28 C (% rdg + digits)	TEMPERATURE COEFFICIENT 0 –18 C and 28 –55 C (% rdg + digits)/ C	NOMINAL APPLIED CURRENT
20 Ω*	19.999	0.05% · 3d	0.004% · 0.6d	1 mA
200 Ω*	199.99	0.05% · 2d	0.004% · 0.2d	1 mA
2kΩ	1.9999	0.04% · 1d	0.004% · 0.2d	1 mA
20kΩ	19.999	0.04% · 1d	0.004% · 0.2d	100 μA
200kΩ	199.99	0.04% · 1d	0.004% · 0.2d	10 μA
2000kΩ	1999.9	0.04% · 1d	0.005% · 0.2d	1 μA
20MΩ	19.999	0.10% · 1d	0.02 % · 0.2d	0.1μA

*Front panel zero

MAXIMUM ALLOWABLE INPUT: 350V peak

OPEN-CIRCUIT VOLTAGE: 5 volts

DC AND TRMS AC CURRENT

RANGE	MAXIMUM READING	ACCURACY (12 months) 18 –28 C (% rdg + digits) DC*	ACCURACY (12 months) 18 –28 C (% rdg + digits) AC 45Hz-10kHz (above 2000 counts)	MAXIMUM VOLTAGE BURDEN
20μA	19.999	0.2% · 2d		0.02V
200μA	199.99	0.2% · 1d	0.8% · 15d	0.2 V
2mA	1.9999	0.2% · 1d	0.8% · 15d	0.2 V
20mA	19.999	0.2% · 1d	0.8% · 15d	0.2 V
200mA	199.99	0.2% · 1d	0.8% · 15d	0.25V
2000mA	1999.9	0.2% · 1d	0.8% · 15d	0.6 V

*Front panel zero

MAXIMUM INPUT: 2A, 250V DC or rms (fuse protected).

TEMPERATURE COEFFICIENT (0 –18 C and 28 –55 C): DC: ±(0.01% + 0.2 digits)/ C except ±(0.01% + 0.6 digits)/ C on the 20μA range. AC: ±(0.07% + 2 digits)/ C.

CREST FACTOR: 3

AC VOLTAGE

RANGE	MAXIMUM READING	ACCURACY (12 months) (above 2000 counts) 18 28 C; 100Hz-10kHz (% rdg + digits)
200mV	199.99	0.5% · 15d
2 V	1.9999	0.5% · 15d
20 V	19.999	0.5% · 15d
200 V	199.99	0.5% · 15d
1000 V	1000.0	0.5% · 15d

EXTENDED FREQUENCY ACCURACY (45Hz-20kHz): ±(0.7% + 15 digits)

TEMPERATURE COEFFICIENT (0 -18 C and 28 -55 C; 45Hz-20kHz): ±(0.05% + 2 digits)/ C

RESPONSE: True root mean square

CREST FACTOR: 3

INPUT IMPEDANCE: 1MΩ ±1% shunted by less than 75pF.

MAXIMUM ALLOWABLE INPUT VOLTAGE: 1000V rms, 1400V peak, 10^7V•Hz maximum.

COMMON MODE REJECTION RATIO (1kΩ unbalance): 60dB at DC, 50Hz and 60Hz.

GENERAL

DISPLAY: Five 0.5" LED digits, appropriate decimal position and polarity indication.

CONVERSION PERIOD: 400 milliseconds.

OVERRANGE INDICATION: Display blinks all zeros above 19999 counts.

MAXIMUM COMMON MODE VOLTAGE: 1400V peak.

ANALOG OUTPUT: Output Voltage: 1V = 10000 counts. **Output Resistance:** 5000 ohms.

ENVIRONMENT: Operating: 0 C to 55 C; 0% to 80% relative humidity up to 40 C. **Storage:** –25 C to +65 C.

CONNECTORS: Input: Binding posts. Output: Banana jacks.

POWER: 105-125 or 210-250 volts (switch selected), 90-110V available. 50-60Hz, 8 watts. Optional 6 hour battery pack, Model 1788.

DIMENSIONS, WEIGHT: 85mm high x 235mm wide x 275mm deep (3½ in. x 9¼ in. x 10¾ in.). Net weight: 1.7kg (4 pounds).

ACCESSORIES AVAILABLE:

Model 1788 Rechargeable Battery Pack: 6 hours operation from full charge, recharges within 14 hours. Field installable. Adds 0.9 kg. (2 lbs.), 7 watts (used on Models 177, 178 and 179)
Model 1600 High Voltage Probe
Model 1651 50 Ampere Shunt
Model 1681 Clip-On Test Lead Set
Model 1682 RF Probe
Model 1683 Universal Test Lead Set
Model 1684 Carrying Case
Model 1685 Clamp-On Current Probe
Model 1010 Rack Mounting Kit
Model 1017 Dual Rack Mounting Kit

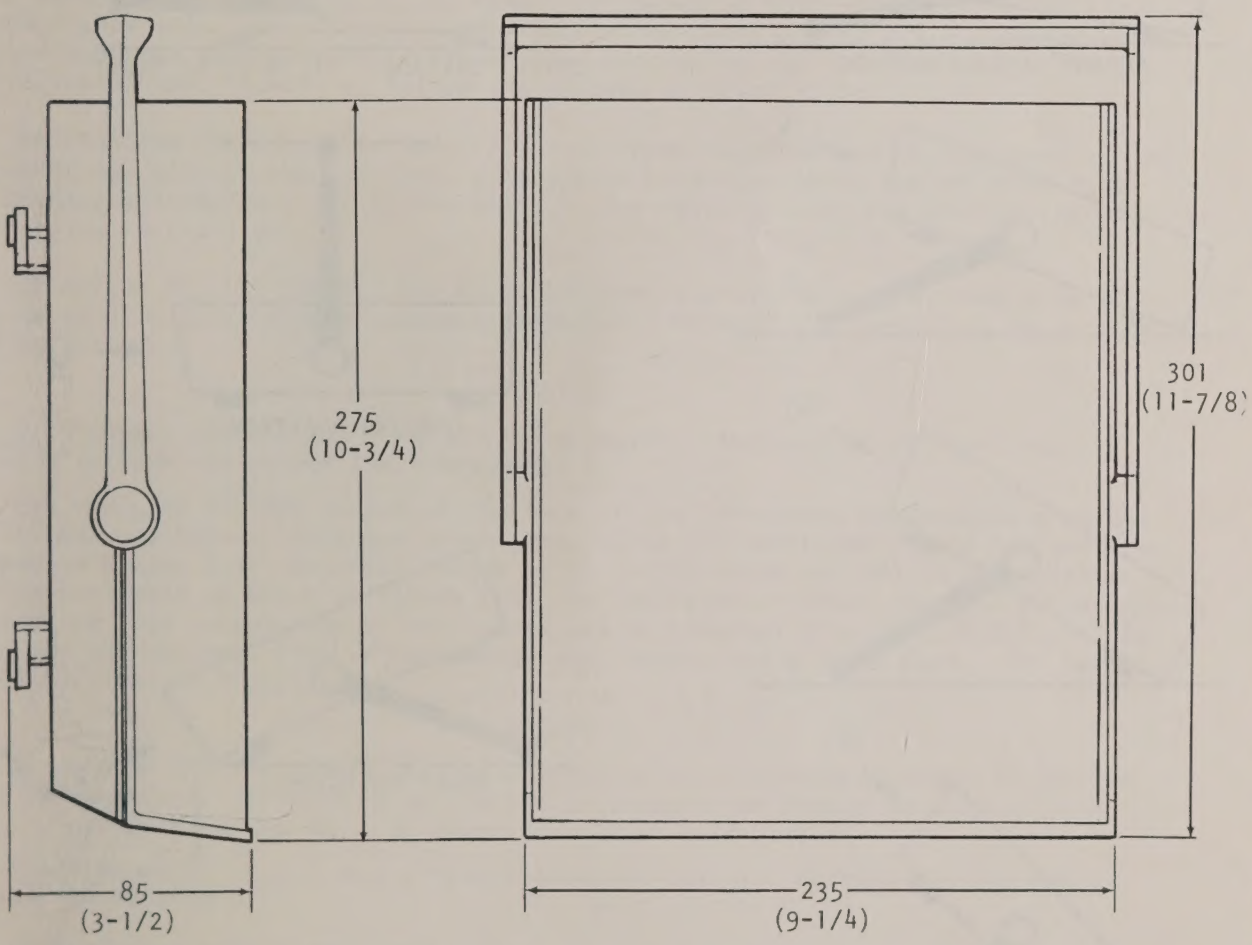


FIGURE 1-2. Dimensional Data.

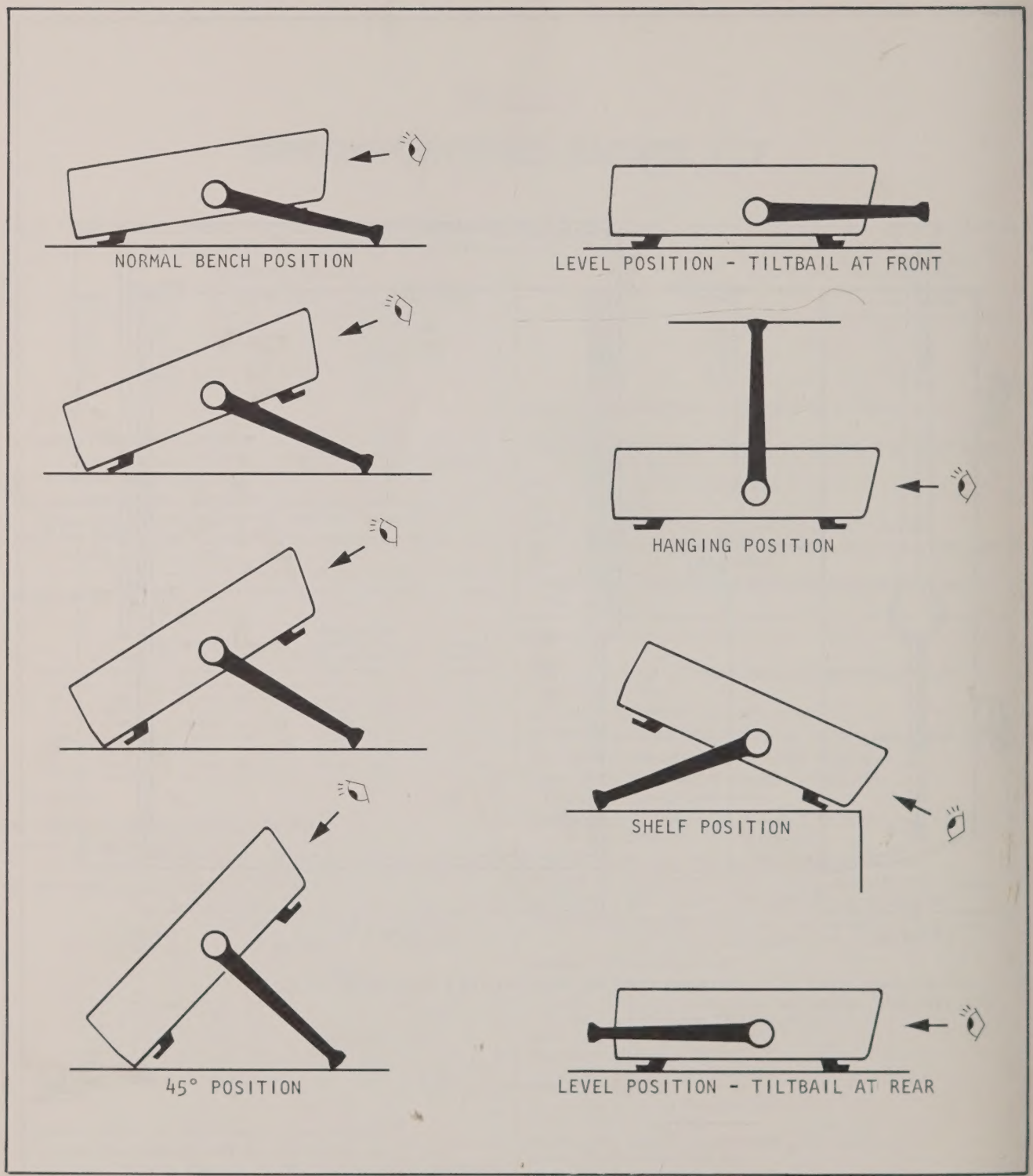


FIGURE 1-3. Tilt Bail Positions.

SECTION 2. OPERATION.

2-1. GENERAL. This section provides information needed for incoming inspection, preparation for use and operation of the Model 177 and Model 1788.

2-2. INSPECTION. The Model 177 was carefully inspected both mechanically and electrically before shipment. Upon receiving the instrument, check for an obvious damage which may have occurred during transit. Report any damages to the shipping agent. To verify the the electrical specifications, follow the procedures given in Section 3.

2-3. PREPARATION FOR USE. The Model 177 is shipped ready-to-use on line power. The instrument may also be powered from rechargeable batteries (when the optional Model 1788 Rechargeable Battery Set is installed.) See Paragraph 2-5 and 2-6 for installation and charging instructions.

2-4. OPERATION ON LINE POWER. The Model 177 DMM is provided with a three-wire line cord which mates with third-wire grounded receptacles. Connect the instrument to ac line power as follows:

CAUTION

⚠ Connect only to the line voltage selected. Application of incorrect voltage can damage the instrument.

a. Set the LINE VOLTAGE switch on the back of the instrument to correspond to the line voltage available. Standard ranges are 105 to 125 volts and 210 to 250 volts ac as shown in Figure 2-1. Optional ranges of 90 to 110 volts and 180 to 220 volts ac are also available as shown in Figure 2-2. As indicated on their respective rear panels, the standard line voltage range instruments use an internal line fuse (F102) of 1/8A rating and the optional line voltage range instruments use a 3/16A fuse. The location of F102 is shown in Figure 2-3.

WARNING

↘ Ground the instrument through a properly earth-grounded receptacle before operation. Failure to ground the instrument can result in severe injury or death in the event of short circuit or malfunction.

b. Plug the power cord into a properly grounded outlet. Operate the 177 DMM as described in SECTION 2-7.

2-5. OPERATION ON BATTERY PACK POWER. The Model 177 DMM may also be operated from rechargeable sealed lead-acid batteries contained in the optional Model 1788 Battery Pack. The battery pack will operate the 177 DMM for up to 6 hours. Circuits within the battery pack will automatically shut down the instrument when the battery charge is insufficient to maintain accurate readings. To install the 1788, refer to Figure 2-3 and perform the following procedure:

WARNING

↘ Disconnect the line cord before removing the case cover.

a. Turn off the power and disconnect the line cord.

b. Turn the DMM bottom side up and loosen the four screws in the bottom cover. These screws are held captive by rubber O-rings.

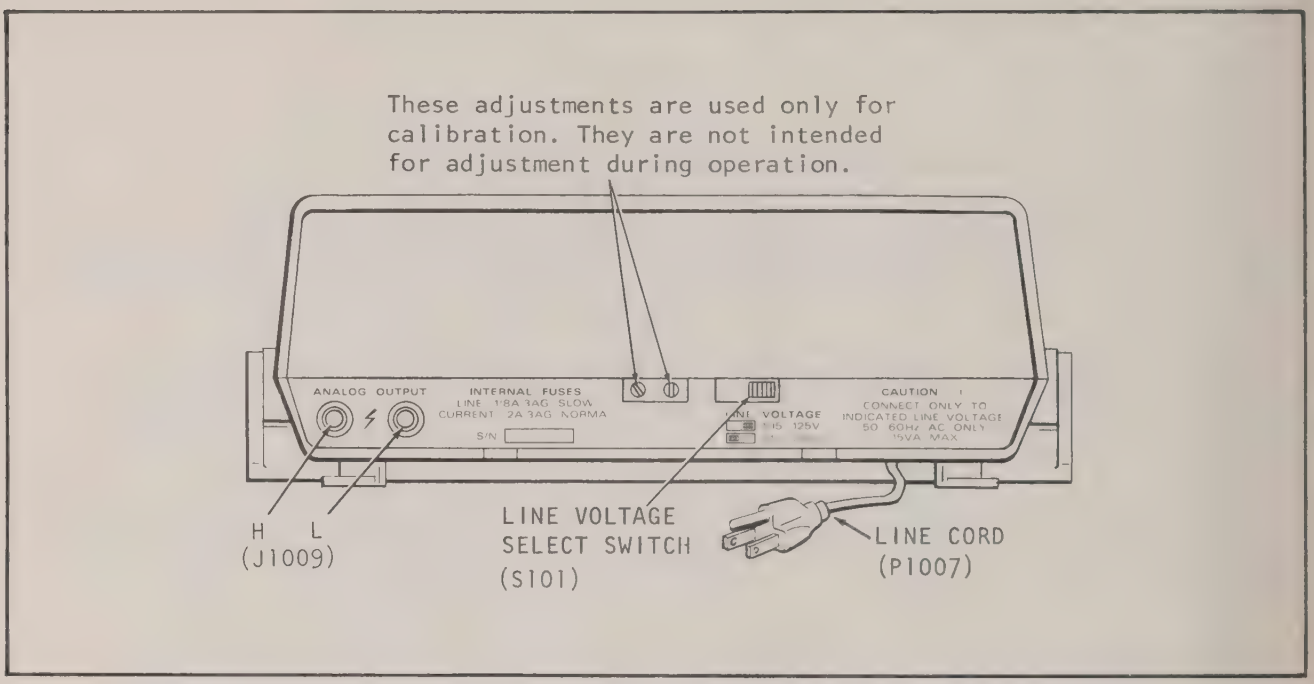


FIGURE 2-1. Rear View of Standard Line Voltage Instruments.

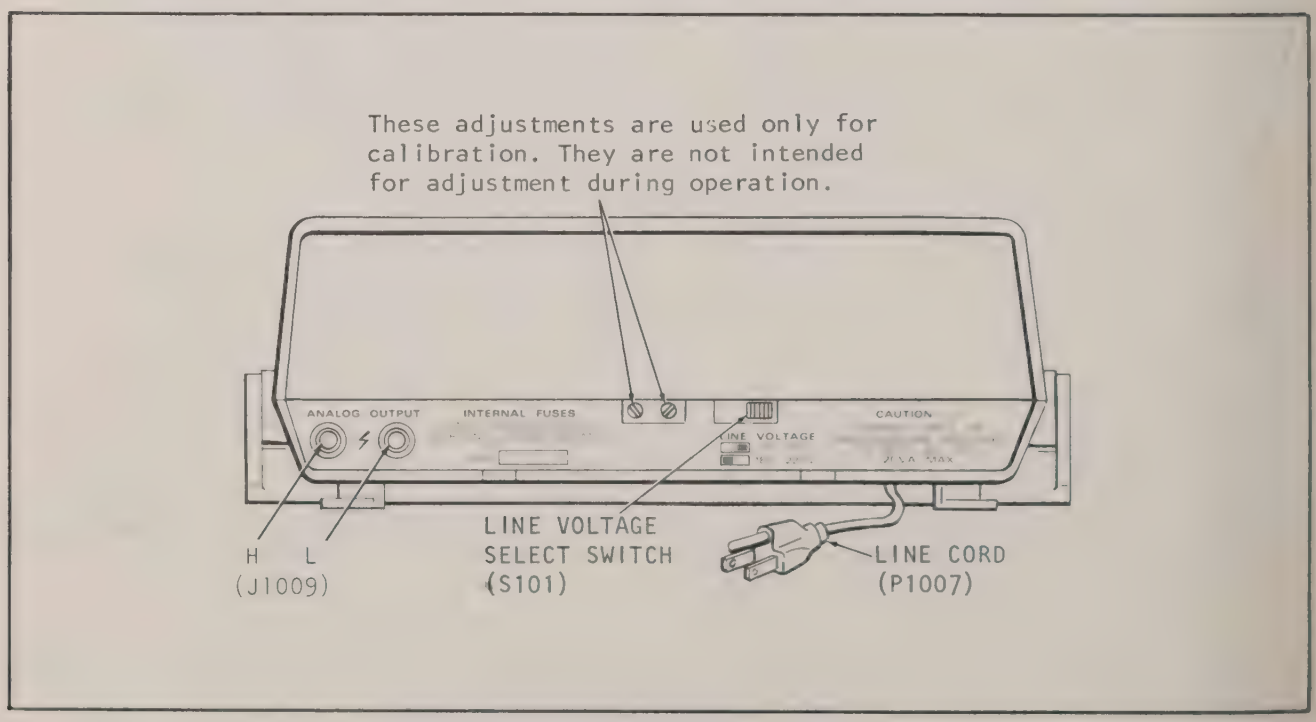


FIGURE 2-2. Rear View of Optional Line Voltage Instruments.

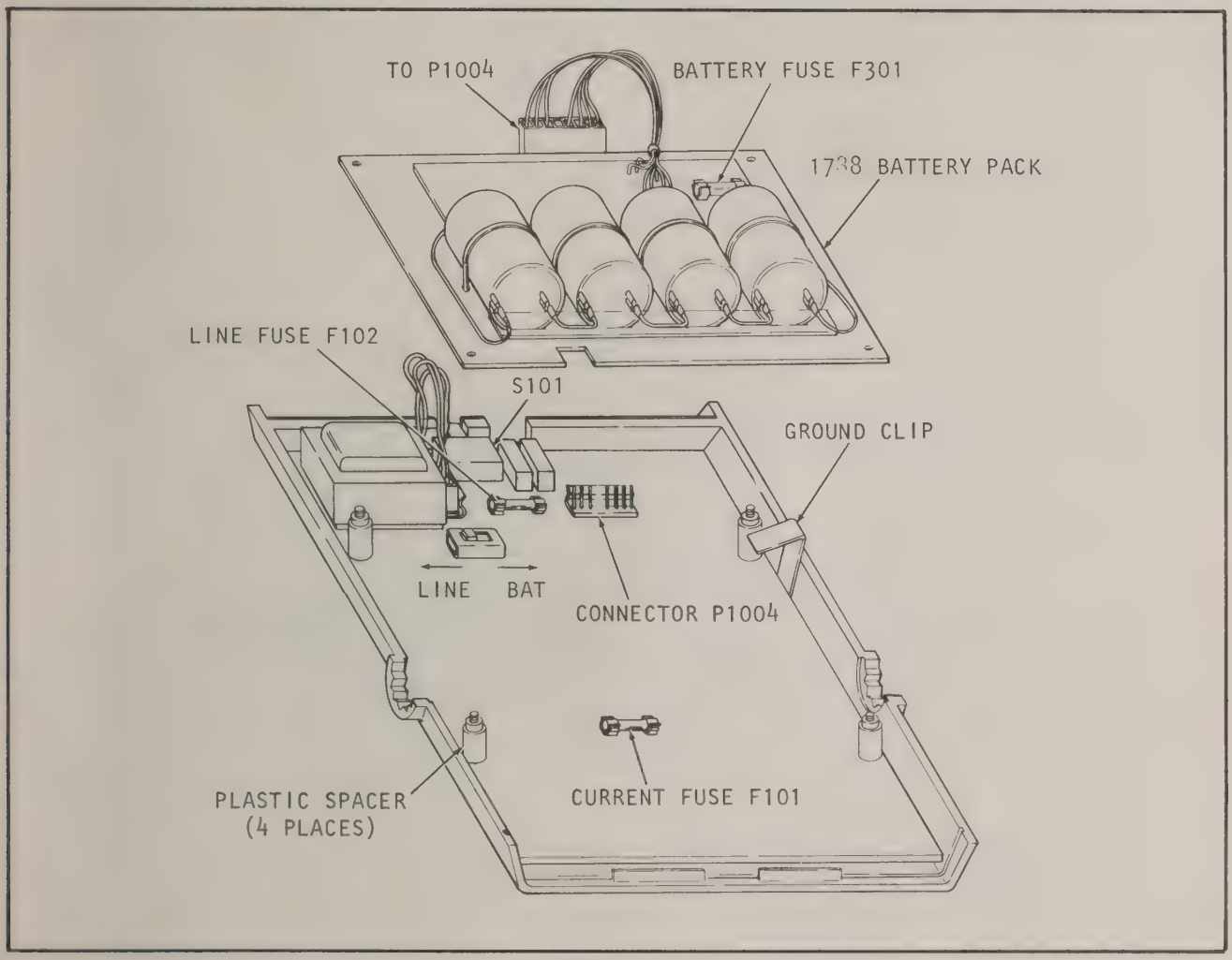


FIGURE 2-3. Battery Pack Installation.

c. Hold the top and bottom covers together to prevent their separation and turn the DMM over to normal position.

d. Lift off the top cover and the calibration shield. The four plastic spacers must remain in place on the upright studs projecting through the main printed circuit board.

NOTE

Do not discard the calibration shield. This shield must be installed during calibration, as described in Section 6.

e. Set the BAT/LINE switch to the BAT position shown in Figure 2-3.. Note that the battery pack will not operate properly if this switch is not in the BAT position.

f. Remove the fuse F301 on the battery pack.

g. Install the battery pack in the instrument so that it rests on the plastic spacers. The ground clip must make contact with the upper side of the battery pack plate.

h. Carefully align the battery pack plug with connector P1004 on the circuit board. Push the plug firmly onto the connector until the lip on the plug engages the lip on the connector to lock the plug in place.

CAUTION

⚠ Make sure the connector is aligned so that all pins mate properly, otherwise, damage to the DMM and battery pack will result.

i. Install fuse F301. Reinstall top cover and secure with four screws.

j. Charge the battery pack as described in Paragraph 2-6.

TABLE 2-1.

MODEL 177 DMM CONDENSED OPERATING INSTRUCTIONS

TO OPERATE:

① Set Power On ② Select Function ③ Select Range ④ Connect Source

① POWER:

Line: Set line switch on rear panel to applicable voltage range. (See manual for fuse location.)

Battery: 6 hour operation after 14 hour charge with Model 1788 field installable battery pack. *(Note 1)*

SUMMARY OF FUNCTIONS, RANGES, AND OTHER INFORMATION

② FUNCTION	③ RANGE *(Note 2)*	ACCURACY 18°C – 28°C *(Note 1)*	INPUT IMPEDANCE	④ MAX. INPUT *(Note 1)*	FRONT PANEL ZERO
DCV (⎓)	20mV	0.04% Rdg + 2D	10MΩ	1200V MOMENTARY	YES
	200mV	0.04% Rdg + 1D			
	2V	0.03% Rdg + 1D		1200V	NO
	20V				
	200V				
	1200V	0.035% Rdg + 1D			
ACV (~) *(Note 3)*	200mV	0.5% Rdg + 15D 100Hz – 10kHz	1MΩ 75pF	1000V RMS 10^7V•Hz	NO
	2V				
	20V	0.7% Rdg + 15D 45Hz – 20kHz			
	200V				
	1000V				
DCA	20μA	0.2% Rdg + 2D	0.02V BURDEN	2A, 250V DC OR RMS *(Note 4)*	YES
	200μA	0.2% Rdg + 1D	0.2V BURDEN		
	2mA				
	20mA				
	200mA		0.25V BURDEN		
	2000mA		0.6V BURDEN		
ACA *(Note 3)*	200μA	0.8% Rdg + 15D 45Hz – 10kHz	0.2V BURDEN	2A, 250V DC OR RMS *(Note 4)*	NO
	2mA				
	20mA				
	200mA		0.25V BURDEN		
	2000mA		0.6V BURDEN		
Ω (OHMS)	20	0.05% Rdg + 3D	20mV F.S.	350V PEAK	YES
	200	0.05% Rdg + 2D	200mV F.S.		
	2k	0.04% Rdg + 1D	2V AT FULL SCALE 5V MAX OPEN CIRCUIT		NO
	20k				
	200k				
	2000k				
	20M	0.1% Rdg + 1D			

ANALOG OUTPUT: ±2V full scale, 5kΩ output resistance *(Note 1)*.

Note 1: See manual for detailed information.
Note 2: Overrange is indicated by flashing 0000
Note 3: True root mean square, crest factor = 3.
Note 4: Current fuse (installed internally) is 2A, 3AG normal blow. See manual for fuse location.

DISCONNECT LINE CORD BEFORE SERVICING.

2-6. BATTERY CHARGING. The Model 1788 Battery Pack contains an integral battery charger. To charge or recharge the battery pack, install the battery pack in the 177 DMM as described above and proceed as follows:

a. Connect the instrument to line power as described in Paragraph 2-4.

b. With the power switch off, the battery charge circuitry is automatically energized to charge the battery at the maximum rate. When the battery pack is first installed, or if it has completely discharged, allow it to charge for at least 14 hours in this condition.

NOTE

For maximum battery life, do not allow the battery pack to remain completely discharged. Constant charging will not harm either the battery pack or the instrument. The Model 177 may be operated up to 6 hours from fully charged batteries. However, since 10 charge/discharge cycles may be required to reach full battery capacity, less than 6 hours DMM operation can be expected when the battery pack is first installed.

c. When the 177 DMM is in use on line power, the battery charger maintains a trickle charge on the battery pack.

2-7. OPERATING INSTRUCTIONS. The basic operating instructions for the Model 177 DMM are outlined below, and Condensed Operating instructions are provided on the bottom cover of the instrument and contained in Table 2-1. These instructions should only be used after becoming completely familiar with the operation of the Model 177 through day-to-day use. Until this familiarity has been achieved, best performance and safest operation will be obtained by using the individual instructions provided in this section which describe how to make specific function measurements. Refer to Figure 2-4 and operate the DMM as follows:

a. Turn on the power by depressing the ON/OFF pushbutton and allow a 10 minute warm-up time. Allow additional warm-up for zero stability on lowest DCV and Ω ranges.

b. Select the function with the AC/DC, Ω, V, or A pushbuttons.

c. Select the range by depressing the appropriate pushbutton.

d. Connect the source to the INPUT terminals. Accessories described in Section 4 should be used as required.

CAUTION

MAXIMUM RATINGS: ⚠

DCV	(20mV, 200mV, 2V): 450V rms continuous; 1200V peak momentary, for up to 8 seconds per minute maximum. (20-1200V): 1200V peak.
ACV	(All Ranges): 1000V rms; 1400V peak; 10^7V·Hz.
DCA, ACA	(All Ranges): 2A, 250V DC or rms (fuse protected).
Ω	(All Ranges): 350V peak, 250V rms.

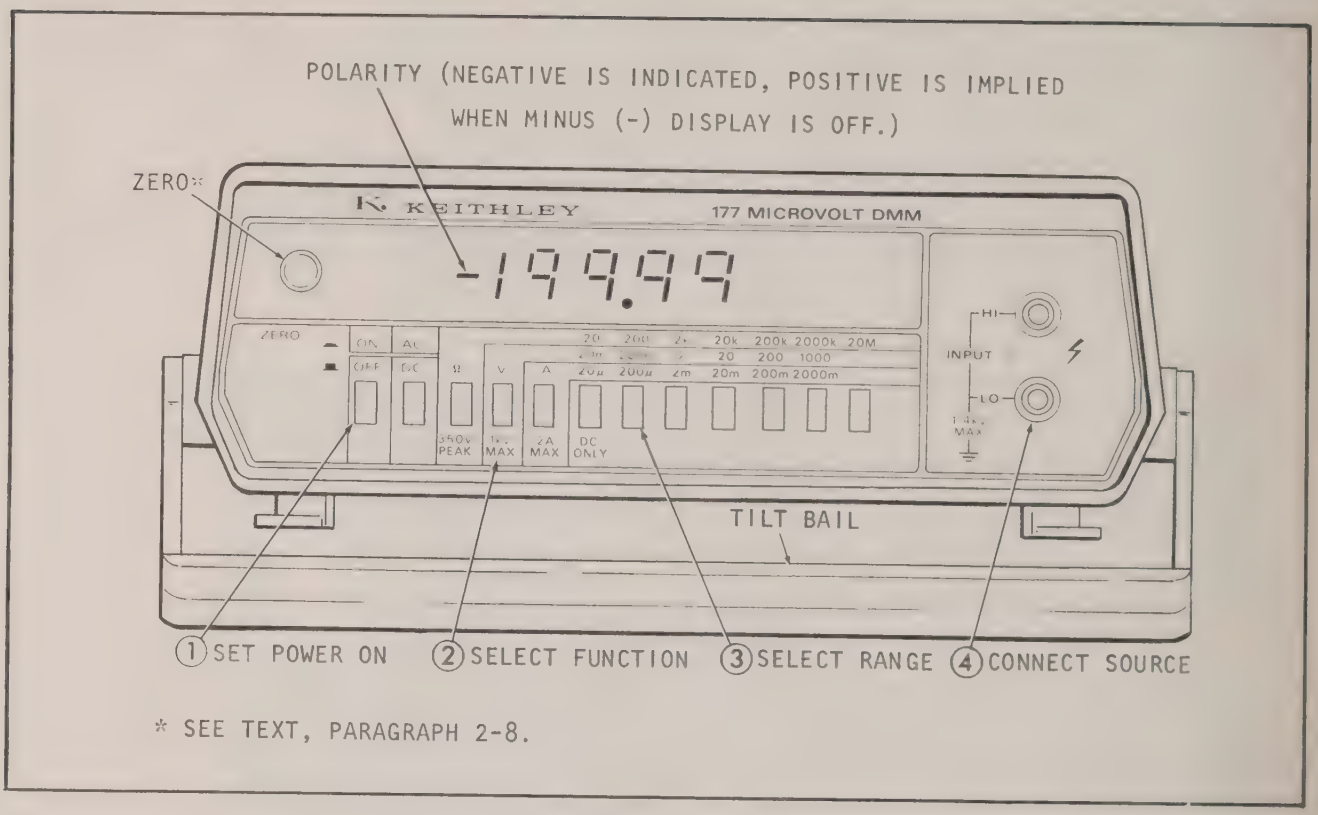


FIGURE 2-4. Operating Controls.

2-8. ZERO ADJUSTMENT. The front panel zero adjustment provides compensation for test lead resistance and thermal emfs' generated in the circuits connected to the DMM input terminals. The zero adjustment is operative on the 20mV and 200mV ranges of DCV, 20 and and 200 Ω ranges and all DCA ranges. In general, the zero must be readjusted whenever the function is changed and the measurement is to be made on a range where the zero adjustment is operative. The accuracy specifications assume that the zero is adjusted on the lowest range of the function. Where applicable, a specific zero adjustment instruction is provided in the description of how to make the particular function measurement.

2-9. DC VOLTAGE MEASUREMENT. The Model 177 detects dc voltages from 1 microvolt/digit to 1200 volts. The maximum displayed reading is 19999. Overrange is indicated by a flashing 0000 except on the 1200 volt range. On the 1200 volt range, the display can read beyond the maximum allowable input voltage. Use the Model 177 to measure dc volts as follows:

CAUTION

⚠ Do not exceed the maximum input voltage ratings. Instrument damage may occur.

a. Turn on power with the ON/OFF pushbutton and select DC with the AC/DC pushbutton.

b. Select the desired range from the six ranges available. The decimal point is positioned by the range pushbutton. The 1200 VDC range is selected by the 1000 pushbutton.

NOTE

The 20M pushbutton is inoperative for dc volts. If this pushbutton is inadvertantly depressed, the 177 will read zero regardless of the voltage applied and the 8 second per minute overload rating will apply.

c. Connect the signal to be measured between the INPUT HI and LO binding posts. The binding posts accept wires, spade lugs or banana plugs for ease of connecting the circuit to be measured. Low thermal cabling and connections are recommended for measurements on the 20mV and 200mV ranges.

d. For the top four ranges, merely observe the displayed digits, polarity sign and decimal point locations. The top four ranges are direct-reading in volts. Nominal settling time is 1 second to within 1 digit of final reading.

e. For the 20mV and 200mV ranges, the front panel ZERO must be adjusted to obtain rated accuracy. This adjustment is necessary to compensate for thermal EMF's generated by the connections to the circuit to be measured. These voltages may be only a few microvolts or several tens of microvolts. The zero adjustment span is set up at the factory to allow at least a ±75μV adjustment. To adjust zero, proceed as follows:

NOTE

Due to the long thermal time constant of the 20mV range zero, a one hour warm-up time may be necessary to adjust zero to the final 1μV setting. Typically, only a one to three microvolt zero shift can be expected during this warm-up period, if the ambient temperature is within the specified 18° to 28°C and the instrument has not been subjected to temperatures outside of this range. Thus, since the expected zero shift is both small and slow, normally zero can be adjusted and several measurements taken without having to achieve the final zero setting.

1) Make connections to the Model 177 as described in Step C above. For the best performance, connections should be made to the binding posts rather than using banana plugs.

2) Set the Model 177 to the 20mV range.

3) Disconnect the leads at the circuit to be measured and short them.

4) Allow the thermal EMF's generated at the connections to stabilize.

5) Adjust the front panel ZERO knob for a display indication of 0.000 mV (a flashing ±0.001 mV is permissable.)

NOTE

The ZERO control operates only on the 20mV and 200mV ranges. It has no effect on the other DC voltage ranges.

6) Make the measurement by applying the signal and reading the millivolts on the display. Nominal settling time for the 20mV range is 3 seconds to within 1 digit of final reading.

NOTE

An overload input to the Model 177 may cause temporary zero shift due to thermal gradients.

7) The zero setting for the 20mV range will also be valid for the 200mV range. Nominal setting time for the 200mV range is 1 second to within 1 digit of final reading.

f. The optional Model 1600 High Voltage Probe can be used with the Model 177 to measure dc voltages up to 40 Kilovolts, at reduced accuracy. Refer to Paragraph 4-4.

2-10. AC VOLTAGE MEASUREMENT. The Model 177 detects ac voltages from 10 microvolts to 1000 volts. The instrument measures the true root means square (TRMS) of a signal within the frequency range of 45 to 20k hertz. The maximum reading is 19999. Overrange is indicated by a flashing 0000 except on the 1000 volt range. On the 1000 volt range, the display can read beyond the maximum allowable input voltage. The maximum crest factor for rated accuracy is 3. AC accuracy is specified for 2000 counts and above. Nominal settling time for all ac voltage ranges is 2.5 seconds to within 10 digits of final reading. Use the Model 177 DMM to measure ac volts as follows:

a. Turn on power and set the AC/DC pushbutton to the in or AC position. Depress the V pushbutton.

NOTE

The 20μ and 20M ranges are inoperative for ac volts. If the 20μ pushbutton is inadvertantly depressed, the display will read overrange, signalling the user to go to the next higher range. If 20M is depressed, the display will read zero regardless of the voltage applied. The method of calibrating the converter may yield an offset up to 80 digits with the Model 177 input shorted. This does not affect the instrument accuracy.

b. Select the desired range from the five ranges available.

CAUTION

⚠ MAXIMUM ALLOWABLE INPUT VOLTAGE (All ranges): 1000V rms, 1400V peak, 10^7V·Hz maximum. Do not exceed the maximum rating. Instrument damage may occur.

c. Connect signal to be measured between INPUT HI and LO terminals. Observe the displayed digits and decimal point location. The 200mV range is direct-reading in millivolts and the remaining four ACV ranges are direct-reading in volts.

d. The crest factor (CF) is the ratio of the peak voltage to the rms voltage as follows:

$$CF = \frac{V_{PEAK}}{V_{RMS}}$$

NOTE

There will be some additional measurement error for signals with a crest factor greater than 3 (CF>3).

1) Typical crest factors are as follows:

Sine Wave	CF = 1.4
Square Wave	CF = 1
Triangular Wave	CF = 1.7
Positive pulse train (duty cycle for CF = 3 is 0.11)	$CF = \sqrt{1/\text{ duty cycle}}$

e. The optional Model 1682 RF Probe can be used with the Model 177 to measure 0.25 V to 30V rms ac signals with a frequency of 20kHz to 100MHz (and above at reduced accuracy.) Refer to Paragraph 4-4.

f. Refer to Paragraph 2-14 for TRMS measurements of a signal with both ac and dc components.

2-11. RESISTANCE (Ω) MEASUREMENT. The Model 177 DMM measures resistance from 1 milliohm/digit to 20 megohms. See Table 2-2 for ranges. Nominal settling times to within 1 digit of final reading are: 3 seconds on the 20Ω range; 2 seconds on the 2000KΩ and 20MΩ ranges; and 1 second on the other four Ω ranges. Use the Model 177 to measure resistance as follows:

a. Turn on power and depress the Ω pushbutton.

CAUTION

⚠ MAXIMUM ALLOWABLE INPUT VOLTAGE (All ranges): 350V peak, 250V rms. Do not exceed maximum rating. Instrument damage may occur.

b. Connect the circuit to be measured to the INPUT binding posts and select the desired range from the seven available.

TABLE 2-2
Resistance Ranges

RANGE SETTING	MAXIMUM READING	FULL SCALE VOLTAGE **	NOMINAL APPLIED CURRENT
20 Ω*	19.999	20mV	1mA
200 Ω*	199.99	200mV	1mA
2KΩ	1.9999	2 V	1mA
20KΩ	19.999	2 V	100μA
200KΩ	199.99	2 V	10μA
2000KΩ	1999.9	2 V	1μA
20MΩ	19.999	2 V	0.1μA
*FRONT PANEL ZERO	ALL RANGES		
	OVERRANGE: FLASHING 0000	OPEN CIRCUIT: 5V MAX.	MAXIMUM ALLOWABLE INPUT: 350V PEAK

** HI binding post (red) is negative.

c. Merely observe the displayed digits and decimal point to measure resistance using the 2K, 20K, 200K, 2000K and 20MΩ ranges. The full scale voltage drop for these ranges is 2 volts which is sufficient to cause forward conduction of semiconductor junctions. The HI (Red) terminal is negative. To measure a resistance in parallel with a semiconductor junction without turning on the junction, either reverse bias the junction or select the next higher Ω range. The latter method is possible because of the 1 decade reduction of applied test current, but will result in a measurement with 3-1/2 digit accuracy. It is suggested that the 2KΩ range be used for diode testing. This range has a nominal 1mA test current and the displayed reading is the forward voltage drop in volts.

NOTE

The front panel ZERO control operates only on the 20Ω and 200Ω ranges. It has no effect on the other resistance ranges.

d. Before making measurements on the 20Ω or 200Ω ranges, adjust front panel ZERO on the 20Ω range to compensate for test lead resistance. Best performance will be obtained on the low ohm ranges when test lead connections are made to the binding posts, rather than using banana plugs. Adjust ZERO and make resistance measurements as follows:

1) Select 20Ω range.

2) Disconnect the test leads at the circuit to be measured and short them. If measurement is to be made right at the INPUT terminals (no test leads used) place a short, such as a piece of copper wire, across the binding posts.

3) Adjust the front panel ZERO knob for a display indication of 0.000 ± 0.001Ω (flashing). The nominal ZERO adjustment span is 200mΩ.

NOTE

The specified accuracy for the 20Ω and 200Ω ranges assumes that ZERO was adjusted on the 20Ω range. Re-adjust zero on the 20Ω range each time that a different set of test leads is used or whenever measurements have been made on either the two lowest dc voltage ranges or any dc current range. The zero setting for those measurements will be different than the zero setting of ohms. Also, re-adjust zero whenever the instrument is used outside the temperature range of 18° to 28°C.

4) Reconnect the test leads to the circuit to be measured.

5) Select either 20Ω range or 200Ω range. Read the displayed digits and decimal point.

NOTE

An input overload to the Model 177 may cause a temporary zero shift due to thermal gradients.

2-12. DC CURRENT MEASUREMENT. The Model 177 DMM measured dc current from 1nA/digit to 2 amperes, over 6 ranges (the 20M range is not operative and the instrument will read zero if 20M pushbutton is depressed). The maximum reading is 19999. Overrange is indicated by a flashing 0000. Overload is protected by fuse F101, a 2 amp 3AG normal-blow fuse. Nominal settling time for dc current ranges is 1 second to within 1 digit of final reading except 3 seconds on 20μA range.

a. Zero Adjustment. Before making dc current measurements, the front panel ZERO must be adjusted on the 20μA range. This adjustment is necessary to remove any offset that was introduced by adjusting ZERO for a low dc voltage measurement or a low Ω measurement. This adjustment will also be necessary whenever the instrument is used outside of the temperature range of 18 to 28°C. The specified accuracy for the dc current ranges assumes that ZERO was adjusted on the 20μA range. Adjust ZERO as follows:

1) Disconnect all circuits from the Model 177 INPUT terminals. The INPUT terminals must have an open circuit.

2) Turn on power and set the AC/DC pushbutton to the out or DC position.

3) Depress A and 20μ pushbuttons.

4) Adjust front panel ZERO knob for a display indication of 0.000μA ± .001 flashing.

b. After adjusting ZERO, use the Model 177 to measure dc current as follows:

CAUTION

⚠ Do not install a larger capacity fuse than the one originally supplied (2A). Current fuse F101 (shown in Fig. 2-3) protects the instrument against overcurrent.

1) Select the desired range from the six ranges available.

2) Connect the circuit to be measured to the INPUT terminals.

3) Read the displayed polarity, digits and decimal point. Select the next higher range if overrange is indicated.

2-13. AC CURRENT MEASUREMENT. The Model 177 measures ac current from 10nA/digit to 2 amperes, over five ranges. (The 20μA and 20M ranges are not operative. See note below.) The 200μA range is direct-reading in microamperes. The remaining ac current ranges are direct-reading in milliamperes. The maximum reading is 19999. Overrange is indicated by a flashing 0000. Overload is protected by fuse F101, a 2A, 3AG normal-blow fuse. The instrument measures the true root mean square (TRMS) of waveforms in the frequency range of 45 to 10K hertz. Use the Model 177 to measure ac current as follows:

a. Turn on power and set the AC/DC pushbutton to in or AC position. Depress the A pushbutton.

CAUTION

⚠ Do not install a larger capacity fuse than the one supplied (2). Current fuse F102 (shown in Fig. 2-3) protects the instrument against overcurrent.

b. Connect the circuit to be measured to the INPUT terminals and select the desired range from the five ranges available.

NOTE

The 20μA and 20M ranges are not operative for ac current measurements. If the 20μA pushbutton is inadvertently depressed, an overrange will be indicated, signaling the user to go to the next higher range. If the 20M pushbutton is depressed, the instrument will read zero.

c. Read the displayed digits and decimal point.

NOTE

AC accuracy is specified for 2000 counts and above. The method of calibrating the converter may yield an offset up to 80 digits with the Model 177 input shorted. This does not affect the instrument accuracy. There will be some additional measurement error for signals with a crest factor greater than 3 (CF>3). Refer to AC Voltage Measurement (Paragraph 2-10d) for information on how to determine the crest factor of a waveform.

d. Refer to Paragraph 2-14 for TRMS measurements of a signal with both ac and dc current components.

2-14. TRMS MEASUREMENT (AC + DC). The Model 177 measures the ac component of a waveform and does not measure the dc component. Use the Model 177 to measure TRMS of a signal which has both ac and dc components as follows:

a. Measure and record the ac and dc components separately.

1) Refer to Paragraph 2-9 for DC Voltage Measurement.

2) Refer to Paragraph 2-10 for AC Voltage Measurement.

3) Refer to Paragraph 2-12 for DC Current Measurement.

4) Refer to Paragraph 2-13 for AC Current Measurement.

b. Compute the TRMS value using the following equation:

$$E_{TRMS} = \sqrt{E_{DC}^2 + E_{AC}^2} \quad \text{OR} \quad I_{TRMS} = \sqrt{I_{DC}^2 + I_{AC}^2}$$

2-15. ANALOG OUTPUT. The rear panel accessible ANALOG OUTPUT provides a ± 2V full scale dc signal (10K counts = 1 volt). The ANALOG OUTPUT is operable for all instrument ranges and functions. The output polarity of the analog voltage is negative for the ohms (Ω) function, positive for AC function and non-inverting for DC functions. The effective analog output resistance is 5KΩ (4KΩ in series with the HI output to protect the Model 177 against externally applied voltage and 1KΩ between input LO and analog output LO to prevent a ground loop when connection is made to a grounded load, oscilloscope or recorder). The analog output voltage is compatible with most modern analog recorders and may be used to determine signal changes with respect to time or other variables. With respect to the signal input and analog output, the Model 177 acts as an amplifier (for microvolt signals), an attenuator (for kilovolt signals) or a converter to dc volts (for ac, current or resistance signals). Output accuracy is the same as the display except on ohms, up to ±0.05% error can be expected due to the ratio-metric method used. The analog output floats at input LO. For this reason, do not connect a voltage source across INPUT LO and ANALOG LO. This will result in a measurement error and may damage the Model 177 if the voltage is greater than 15 volts. When the instrument is in an overrange condition, up to ±15 volts dc may be at the ANALOG OUTPUT dependent upon the function, range and level of the input signal.

SECTION 3. PERFORMANCE VERIFICATION.

3-1. GENERAL. Performance verification may be performed upon receipt of the instrument to ensure that no damage or misadjustment has occurred during transit. Verification may also be performed whenever there is question of the instrument's accuracy, and following calibration, if desired.

NOTE

For instruments that are still under warranty (Less than 12 months since date of shipment), if the instrument's performance falls outside specifications at any point, contact your Keithley representative or the factory immediately.

3-2. RECOMMENDED TEST EQUIPMENT. Recommended test equipment for performance verification is listed in Table 3-1. Alternate test equipment may be used. However, if the accuracy of the alternate test equipment is not at least 10 times better than the instrument specifications, additional allowance must be made in the readings obtained. Some of the equipment listed in Table 3-1 is not 10 times better than the 177 specifications because such equipment is not readily available. In these instances, the verification procedures indicate the equipment manufacturer's specified uncertainty, and include the uncertainty in determining the allowable reading for the Model 177.

3-3. ENVIRONMENTAL CONDITIONS. All measurements should be made at an ambient temperature within the range of 18° to 28°C (65° to 82°F), and a relative humidity of less than 80%.

3-4. PERFORMANCE VERIFICATION PROCEDURE. Use the following procedures to verify the basic accuracy of the Model 177 DMM for voltage, resistance and current measurements. If the instrument is out of specifications at any point, perform a complete calibration as described in Section 6, unless the instrument is still under warranty, as noted above.

TABLE 3-1.
Recommended Test Equipment For Performance Verification.

ITEM	DESCRIPTION	SPECIFICATION	MFR.	MODEL
A	DC Calibrator	0.19V, 1V, 10V, 100V, 1000V ±0.002% or 20μV	Fluke	343A
B	AC Calibrator	0.1V, 1V, 10V, 100V ±0.022%	H-P	745A
C	AC Calibrator/Amplifier	1000V @ ±0.04%	H-P	745A/746A
D	Decade Resistor	190Ω, 1.9KΩ, 19KΩ, 190KΩ, 1.9MΩ, 10MΩ, ±0.01%	ESI	RS725
E	Current Source	100μA, 1mA, 10mA, ±0.006%	Fluke	3330B
F	Current Source	100mA, 1A, ±0.02%	Fluke	382A
G	100Ω Per Step 4-Terminal Low Thermal Resistor	10:1 divider within 50 PMM	ESI	SR1010

NOTE

Performance verification should be performed by qualified personnel using accurate and reliable test equipment.

a. Initial Conditions. Before beginning the verification procedure the instrument must meet the following conditions:

1) If the instrument has been subjected to extremes of temperature, allow internal temperatures to stabilize for one hour minimum at the environmental conditions specified in Paragraph 3-3.

2) Turn on the 177 DMM and allow it to warm up for 1 hour. The instrument may be operated from either line power or from battery pack power, as long as the battery pack has been fully charged as described in Paragraph 2-6.

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death.

b. DC Voltage Accuracy Check (2V to 1200V Ranges).

1) Select dc voltage function with the AC/DC and V pushbuttons.

2) Connect the DC Calibrator (Item A, Table 3-1) to the instrument.

3) Select the 2V range, and apply positive 2Vdc to the DMM. The reading must be within the limits specified in Table 3-2.

4) Select each remaining range and apply required voltage specified in Table 3-2. Verify that the reading is within specifications.

5) Repeat all checks with negative voltage.

TABLE 3-2.

DC Voltage Performance Check (2V to 1200V Range)

Range	Applied Voltage	Allowable Readings at 18° to 28°C
2 V	1.0000 V	0.9996 to 1.0004
20 V	10.000 V	9.996 to 10.004
200 V	100.00 V	99.96 to 100.04
1200 V	1000.0 V	999.5 to 1000.5

c. DC Voltage Accuracy Check (20mV and 200mV Ranges).

1) Select DCV and 20mV range.

2) Disconnect test leads at the DC Calibrator (A) and short them. Adjust Model 177 front panel ZERO for a display indication of 0.000mV ±0.001mV flashing.

3) Connect the DC Calibrator and select 200mV range.

4) Set the DC Calibrator to an output of +0.190000V.

5) Verify that the Model 177 reading is between +189.89 to +190.11mV. Note that the allowable reading includes a ±2 digit allowance for the uncertainty of the DC Calibrator (A).

6) Repeat steps 4 and 5 with negative voltage.

7) Select 20mV range.

8) Connect the DC Calibrator (A), Low Thermal Resistor (G) and Model 177 as shown in Figure 3-1.

9) Temporarily disconnect the test leads from the DC Calibrator and short them. Adjust Model 177 front panel ZERO for a display indication of 0.000 ±0.001mV flashing.

10) Set the DC Calibrator to an output of +0.190000V.

11) Verify that the Model 177 reading is between +18.987 and +19.013mV. Note that the allowable reading includes ±2 digits for DC Calibrator (A) uncertainty and ± 1 digit for Low Thermal Resistor (G) uncertainty.

12) Repeat steps 10 and 11 with negative voltage.

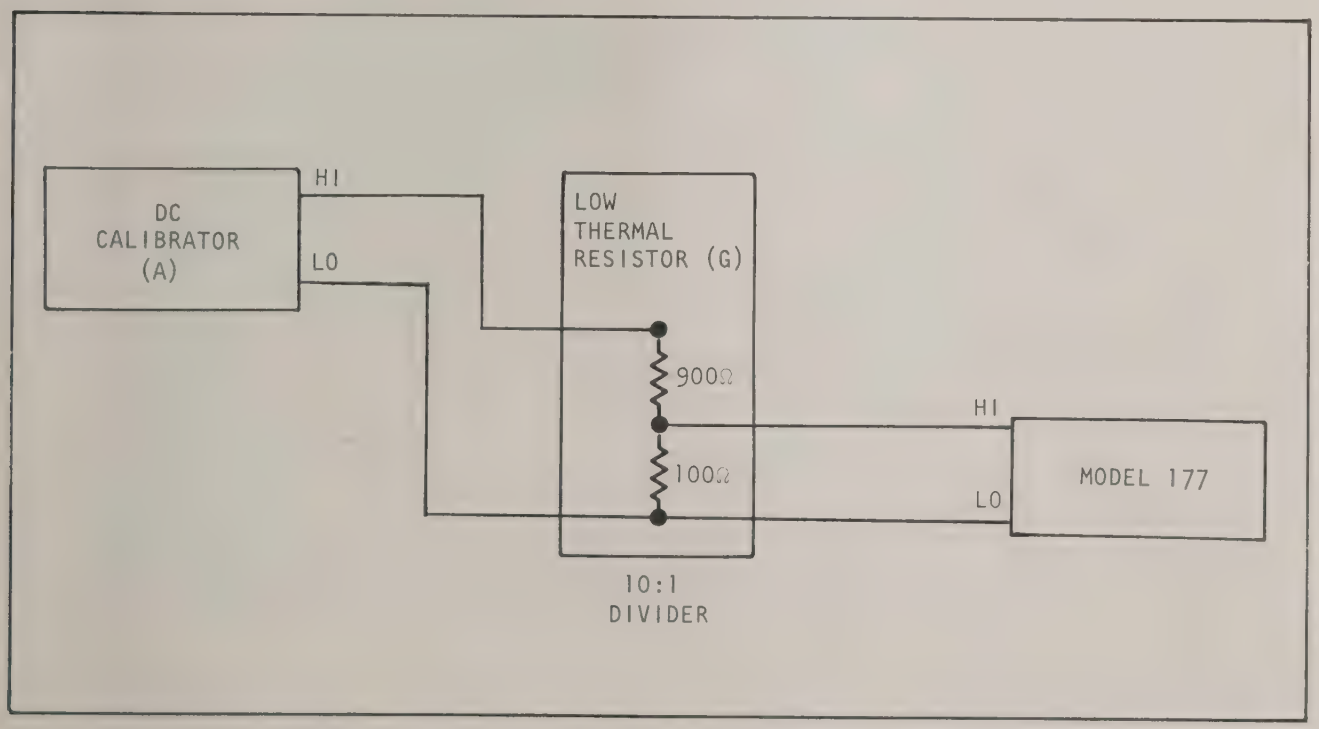


FIGURE 3-1. Test Circuit For 20mV DC Accuracy Check.

d. AC Voltage Accuracy Check.

1) Select ac voltage function with the AC/DC and V pushbuttons.

2) Connect the AC Calibrator (Item B, Table 3-1) to the DMM. Set the calibrator frequency to 1 kHz.

3) Set the DMM to the 200mV range and apply 100mV ac to the DMM. The reading must be within the limits specified in Table 3-3.

4) Select the 2, 20 and 200 volt ranges and apply the required voltages as specified in Table 3-3. Verify that the readings are within specifications.

5) To check 1000 volt range, connect the AC Calibrator Amplifier (Item C, Table 3-1) to the output of the AC Calibrator per the manufacturer's instructions. Connect the Amplifier output to the Model 177 INPUT terminals. Set the AC Calibrator for Amplifier output of 1000.000 volts @ 1 kHz. Verify that the DMM reading is within the specified limits in Table 3-3.

6) To Check accuracy at 45 Hz and 20 kHz, select the 20 volt range. Apply the voltage specified in Table 3-3 at 45 Hz, then repeat at 20 kHz. Verify that the DMM readings are within the specified limits.

TABLE 3-3.
AC Voltage Accuracy Check.

Range	Applied Voltage	Allowable Readings at 18° to 28°C
	@ 1kHz	
200 mV	100.00 mV	99.35 to 100.65 mV
2 V	1.0000 V	0.9935 to 1.0065 V
20 V	10.000 V	9.935 to 10.065 V
200 V	100.00 V	99.35 to 100.65 V
1000 V	1000.0 V	993.5 to 1006.5 V
	@ 45Hz	
20 V	10.000 V	9.915 to 10.085 V
	@ 20kHz	
20 V	10.000 V	9.915 to 10.085 V

e. Resistance (Ω) Accuracy Check.

1) Select resistance function by depressing Ω pushbutton.

2) Select 200Ω range.

3) Connect the decade resistor (Item D, Table 3-1) to the DMM.

4) Set the decade resistor to zero and compensate for lead resistance by adjusting front panel ZERO for a display indication 00.00 ± 0.01 Ω flashing.

5) Set the decade resistor to 190Ω. Verify that the reading for the 200 Ω range is within the limits specified in Table 3-4.

6) Select the 2k Ω range.

7) Set the decade resistor to zero and measure the resistance of the test leads. Subtract this reading from the displayed reading in all of the following steps.

8) Set the decade resistor to 1.900KΩ. Verify that the reading is within the limits specified in Table 3-4.

9) Continue by selecting the next range and measure the next resistance as specified in Table 3-4. Test each item in the table and verify that each reading is within specifications.

TABLE 3-4.
Resistance Accuracy Check.

RANGE	RESISTANCE	ALLOWABLE READING AT 18° to 28°C	*
200 Ω	190 Ω	189.86 to 190.14 Ω	± 2 digits
2K Ω	1.900 KΩ	1.8989 to 1.9011 KΩ	± 2 digits
20K Ω	19.000 KΩ	18.989 to 19.011 KΩ	± 2 digits
200K Ω	190.00 KΩ	189.89 to 190.11 KΩ	± 2 digits
2000K Ω	1900.0 KΩ	1898.9 to 1901.1 KΩ	± 2 digits
20M Ω	10.000 MΩ	9.988 to 10.012 MΩ	± 1 digits

* Manufacturer's specified uncertainty of the decade resistor (D) in digits. This uncertainty has been added to the specified accuracy of the Model 177 to obtain the allowable reading.

f. DC Current Accuracy Check.

1) Select the dc current function with the AC/DC and A pushbutton.

2) Select the 20μA range. With an open circuit at the INPUT terminals of the Model 177, adjust the front panel ZERO for a display indication of 0.000 ±0.001μA flashing.

3) Connect the dc current source (Item E or F, Table 3-1) to the DMM.

4) Select each range and apply the required current as specified in Table 3-5. Verify that each reading is within specifications.

g. Analysis. If the instrument is out of specified limits at any point in Table 3-2 through 3-5, calibrate the DMM as described in Section 6. If the unit is still under warranty, refer to the note in Paragraph 3-1.

TABLE 3-5.
DC Current Accuracy Check.

Range	Applied Current	Allowable Reading at 18° to 28°C
200 μA	100.00 μA	99.79 to 100.21 μA
2 mA	1.0000 mA	0.9979 to 1.0021 mA
20 mA	10.000 mA	9.979 to 10.021 mA
200 mA	100.00 mA	99.79 to 100.21 mA
2000 mA	1000.0 mA	997.9 to 1002.1 mA

NOTE

It is not necessary to specifically check 20Ω or 20μA ranges, or any of the ACA ranges. The circuit components that determine their accuracy have been checked elsewhere in the verification procedure.

SECTION 4. ACCESSORIES.

4-1. GENERAL. This section describes the various accessories and options available for use with the Model 177 Microvolt DMM.

4-2. POWER OPTIONS. The Model 177 can be powered by line voltage (105-125V@ 50-60Hz or 210-250V@ 50-60Hz - Standard ranges) or the optional Model 1788 Rechargeable Battery Pack. (Optional line voltage ranges are described in Section 2.) The Model 1788 is available factory-installed or field-installable. Installation and operating instructions are given in Section 2.

4-3. CONVENIENCE CABLES AND CONNECTORS. The following cables and connection kits enable effective use of the Model 177.

a. Model 1681 Clip-On Test Lead Set. This set (shown in Figure 4-1) contains two leads with banana plugs at one end and spring-action clip-on probes at the other end. To use, insert the banana plugs into the DMM and attach the probes to the source.

b. Model 1683 Universal Test Lead Kit. This kit (shown in Figure 4-1) contains two test leads and 12 screw-in adapter tips. The tips consist of two alligator tips with boots, two banana plugs, two needle tips with chucks, two spade lugs and four heavy duty tip plugs which permit connection of the DMM to virtually any source within its measurement range.

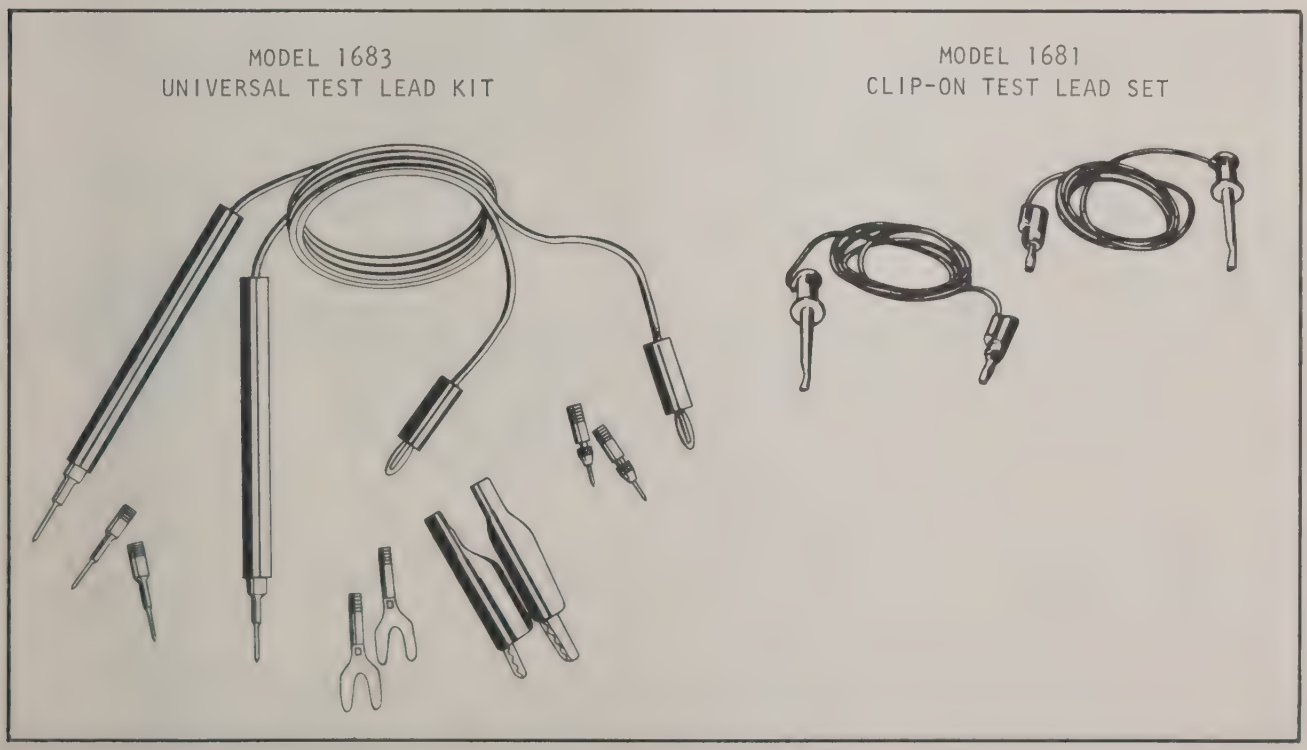


FIGURE 4-1. Convenience Cables and Connectors.

4-4. PROBES AND SHUNTS. The following probes and shunts extend the capabilities of the Model 177.

a. Model 1600 High Voltage Probe. The Model 1600 High Voltage Probe (shown in Figure 4-2) extends the measurable dc voltage range up to 40 kilovolts. It has a 1000:1 division ratio, so that a reading of 1 volt on the DMM corresponds to 1 kilovolt (1000 volts). To use the probe, select DCV and the required range, connect the high voltage probe banana plug to the instrument, connect the alligator clip to source low, and touch the probe tip to source high.

WARNING

Be sure alligator clip is connected to source low before touching probe tip to source high. A shock hazard or damage to instrument may result.

SPECIFICATIONS:

Voltage Range: 0 to 40,000 volts DC.
Input Resistance: 1000 megohms.
Division Ratio: 1000:1.
Ratio Accuracy:
±1.5% at 25kV, decreasing to
±2.0% at 20kV and 20kV,
±2.0% at 10kV and 40kV, and
±4.0% at 1kV.
Ratio Stability: ±0.01% per °C; ±0.1% per year.
Heating Effects: Self-heating due to application of high voltage for period in excess of 1 minute will cause a maximum of 0.2% additional error at 40kV (error is less at lower voltage).

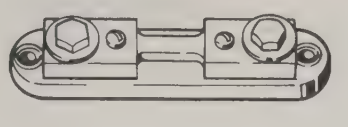
b. Model 1651 50-Ampere Shunt. The Model 1651 50-Ampere Shunt (shown in Figure 4-2) permits current measurements of up to 50 amperes ac or dc. The shunt has a resistance of 0.001 ohm ±1%, so that a 50-ampere current will correspond to a reading of 50 millivolts (0.0500 volt). Set the DMM to ACV or DCV and select the required range. To use the shunt, connect the leads furnished with the shunt from the shunt screw terminals to the DMM input terminals. Use separate leads (not furnished) to connect the source to the hex head bolts. Be sure to use leads with a capacity of 50 amperes, or as needed.

c. Model 1682 RF Probe. The Model 1682 RF Probe (shown in Figure 4-3) permits measurement of ac voltages at frequencies of 20 kilohertz to 100 megahertz. Connect the probe to the input terminals and select DCV and the approriate range.

SPECIFICATIONS:
Voltage Range: 0.25 to 30 volts rms.
Transfer Accuracy: ±0.5dB, 100kHz to 100MHz peak responding calibrated in rms of a sinewave.
Input Impedance: 4 megohm shunted by 3pF.
Maximum Allowable Input: 30V rms AC,, 200V DC.
Accessories Supplied: straight-tip, hook tip, ground clip, hi adapter, banana plug adapter.

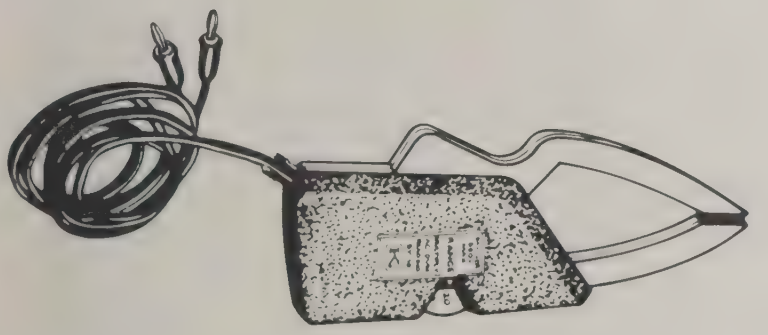
d. Model 1685 Clamp-On AC Current Probe. The Model 1685 Clamp-On AC Current Probe (Shown in Figure 4-3) permits measurement of ac current by clamping around a single conductor, eliminating the need to interrupt the current path. Plug the ac current probe into the DMM and select ACV and the appropriate range. The DMM will display 0.1 volt rms per ampere.

MODEL 1600
HIGH VOLTAGE PROBE

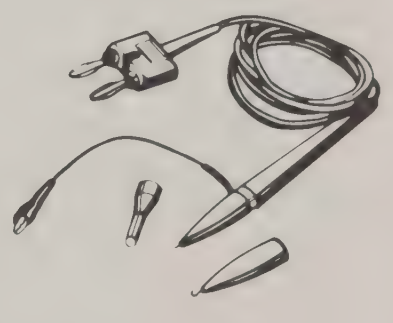


MODEL 1651
50-AMPERE SHUNT

FIGURE 4-2. Model 1600 High Voltage Probe and Model 1651 50-Ampere Shunt.



MODEL 1685
CLAMP-ON AC CURRENT PROBE



MODEL 1682
RF PROBE

FIGURE 4-3. Model 1682 RF Probe and Model 1685 Clamp-On AC Current Probe.

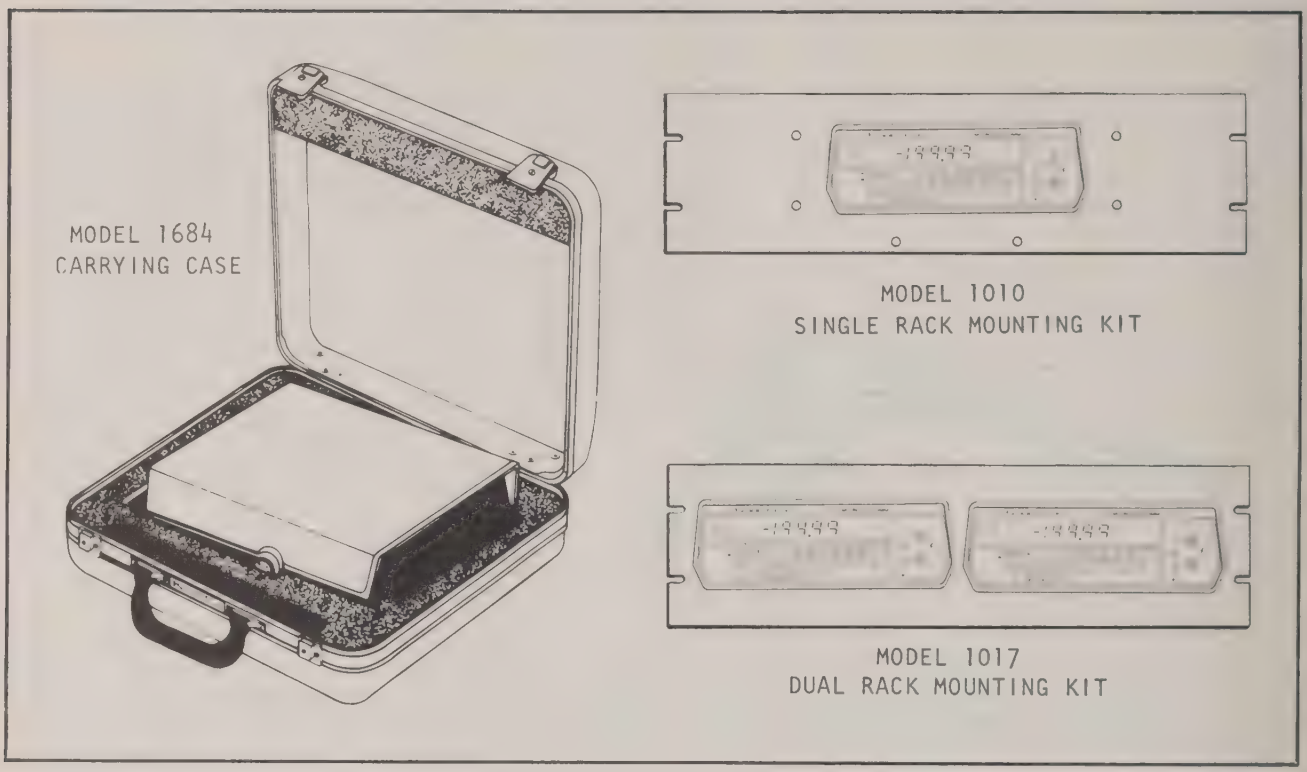


FIGURE 4-4. Carrying Case and Rack Mounting Kits.

4-5. CARRYING CASE AND RACK MOUNTS.

a. Model 1684 Carrying Case. The Model 1684 Carrying Case (Shown in Figure 4-4) is a hard vinyl case with a fitted foam insert to help protect the Model 177 from damage. There is also room in the case for the Instruction Manual and small accessories.

b. Models 1010 and 1017 Rack Mounting Kits. The rack mounting kits (shown in Figure 4-4) permit mounting one or two Model 177 DMM's in a 19-inch rack for convenient viewing.

SECTION 5. THEORY OF OPERATION.

5-1. GENERAL. This section contains circuit descriptions for the Model 177 DMM and the optional Model 1788 Battery Pack. An overall block diagram of signal flow is provided in Figure 5-1. The schematic diagrams are contained in Section 7 of this manual. The Model 177 Schematic is #29658E and Schematic #29659C is for the Model 1788.

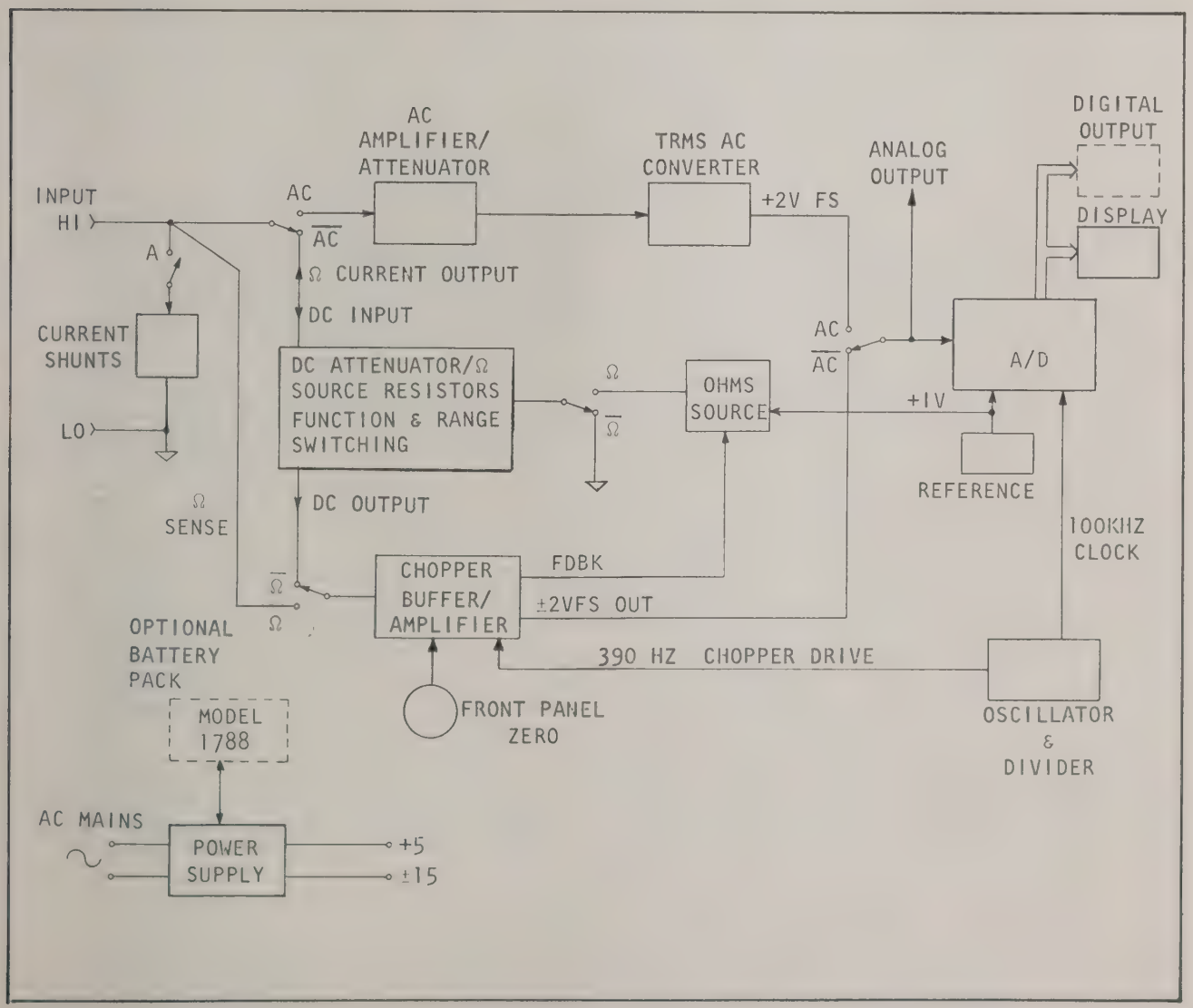


FIGURE 5-1. Simplified Signal Flow Block Diagram, Model 177 DMM.

5-2. OVERALL OPERATION. The Model 177 DMM uses a 2-volt (20,000 count) full scale analog-to digital (A/D) converter with a 4-1/2 digit multiplexed display. Signal conditioning permits the A/D converter to accommodate full scale dc voltage and current measurements over 6 ranges, ac voltage and current measurements over 5 ranges and resistance measurements over 7 ranges.

a. Signal Conditioning. Signal conditioning includes dc attenuation (on the 20, 200 and 1200 volt ranges), modulation and demodulation of the DC signal by the chopper buffer/amplifier with X100 and X10 gain (on the 20 and 200 mV ranges, respectively), ac attenuation (on the 20, 200 and 1000 volt ranges), ac amplification (on the 200 mV and 20 volt ranges), ac-to-dc conversion, ohms source and conversion, and current shunts as shown in Figure 5-1.

1) In the DCV mode, signal conditioning to the A/D converter consists of range and function switching, range resistors (attenuator) and the chopper buffer/amplifier. For all ranges, the dc input signal is attenuated/amplified to provide a ± 2 volt full scale output to the A/D converter. In the DCA mode, the voltage developed across the shunt resistor is applied direct to the input of the chopper amplifier. A chopper gain of X10 is used for all ranges except 20μA which uses X100.

2) In the ACV mode, ac inputs for all ranges pass through the ac converter which consists of an amplifier/attenuator and a TRMS converter, as shown in Figure 5-2. The ac input is scaled by the amplifier/attenuator to 2 volts rms full scale for all ranges. The TRMS converter provides a positive dc output signal which is proportional to the true root mean square ac signal. This dc signal is the input to the A/D converter. In the ACA mode, the shunt voltage is applied to the input of the ac converter. The amplifier/attenuator provides a X10 gain for all ac current ranges.

3) Ohms conversion. Resistance measurements are made by supplying a constant current from the ohms converter to the unknown resistor (R_X). The resulting voltage developed across the unknown resistor is proportional to its resistance, and this voltage is applied to the input of the chopper amplifier used for dc volts. The chopper amplifier output to the A/D converter is scaled to -2 volts full scale for all ohms ranges. Scaling of the ohms signal over the seven ranges is accomplished by using 5 constant current levels and the 3 gains of the chopper amplifier.

b. A/D Converter. The A/D converter is a large scale integration (LSI) ratiometric device. Converter output is a multiplexed 5 digit number, in binary coded decimal (BCD) form which is equal to the ratio of the input voltage to the reference voltage. A separate clock circuit supplies a 100 kHz timing input to the integrated circuit, which also multiplexes the BCD output. The full scale A/D input for all ranges of the Model 177 is 2 volts dc, with the polarity determined by the function as follows: (1) ACV and ACA, + 2 volts; (2) DCV and DCA, ± 2 volts; (3) Resistance (Ω), -2 volts.

c. Range Switching. It is important to note that the range switches on Schematic 29658E are identified by the front panel marking for the Ω ranges. The corresponding V and A ranges may either be determined from the instrument front panel or by using Table 5-1.

TABLE 5-1.
Range Switch Correlation

Function	Ranges						
Ω	20	200	2K	20K	200K	2000K	20M
V	20m*	200m	2	20	200	1000**	
A	20μ*	200μ	2m	20m	200m	2000m	

* DC Only
** ACV 1000, DCV 1200

5-3. AC CONVERTER. When making AC voltage measurements, the AC converter scales the input signal by appropriate attenuation or amplification, performs TRMS conversion and provides the equivalent positive dc level to the A/D for display. Input resistance for ac volts is 1MΩ (R107). Shunt capacitance is less than 75pF. Signal conditioning is as follows:

a. Scaling. Scaling is performed in the first two stages, as shown on Schematic No. 29658E and summarized in Table 5-2. Scaling is performed by using a relay and FET switches to switch feedback resistors in the attenuator (U101) and the amplifier (U102). The actual gains used in attenuator U101 are 0.99, 0.0099 and 0.00099. Amplifier U102 gains are nominally 1.003 and 10.03. The combined gain of U101 and U102 is offset low to permit gain adjustment in the TRMS stage. The only adjustments provided in the attenuator and amplifier stages are two high frequency compensation capacitors (C102 and C103). AC coupling is used at the input and output of the attenuator and amplifier stages. Input overload protection is provided by diodes (CR106 and CR107) and resistor R107 (1MΩ, 2 watts).

TABLE 5-2.
AC Converter Attenuation and Amplification.

RANGE	ATTENUATOR (U101)	AMPLIFIER (U102)
200mV	:1	x 10*
2 V	:1	x 1
20 V	:100**	x 10*
200 V	:100**	x 1
1000 V	:1000***	x 1

* x 10 = Q102 Off
** x 100 = Q101 On
*** x 1000 = K101 On

b. AC Conversion. AC-to-DC conversion is performed by a monolithic TRMS module (U103). Output $V_{dc} = \sqrt{Avg\ (Vin)^2}$. Averaging and output filtering are done before the internal output buffer to give a low impedance for the Analog Output. Potentiometer R113 provides midband (10K count) gain adjustment and R114 establishes output zero (1K count).

Capacitor C108 is used in the averaging circuit, and C109 provides filtering as described above.

d. AC Current Measurements. For ac current measurements, the appropriate shunt resistor is placed in front of the AC converter. The 200mV range gain configuration is used for all current ranges.

5-4. DC SIGNAL CONDITIONING. For dc voltage measurements, the input resistance is 10MΩ, which is established by all of the range resistors being connected in series to signal ground. On low voltage ranges, the DC input is applied to the top of the resistive divider (range resistor) and to the buffer amplifier input without attenuation. And the chopper amplifier has appropriate gain to provide a ± 2 volts full scale output to the A/D. On high voltage ranges, the DC signals are scaled down to ±2 volts full scale by the resistive divider and the chopper is used in the unity gain (follower) mode as a buffer. A summary of input attenuation and chopper amplifier gain is given in Table 5-3.

TABLE 5-3.
DC Signal Conditioning Attenuation and Gain.

RANGE	INPUT ATTENUATION	CHOPPER GAIN
20mV	-----	x 100
200mV	-----	x 10
2 V	-----	x 1
20 V	: 10	x 1
200 V	: 100	x 1
1200 V	: 1000	x 1

a. Input Attenuation. On the 20, 200 and 1200 volt ranges, the input signal is attenuated by the resistive divider to divide by 10, 100 and 1000, respectively. Depressing one of the above range pushbuttons, interrupts the unattenuated signal from the volts switch pin 17 and connects the wiper of the appropriate range potentiometer to the input of the chopper. Division by 10, 100 or 1000 is accomplished by connecting the wiper of R155, R156 or R157, respectively.

b. Chopper. The input signal to the chopper is filtered and applied to a modulator circuit. The ac signal is then amplified and demodulated. A final high gain dc amplifier provides a dc signal to the A/D converter and the Analog Output.

1) Modulator circuit. This circuit converts the input dc signal to an ac signal with a fundamental frequency component of approximately 390 Hz. This frequency was chosen because it reduces the amplitude of higher harmonics of the 50 Hz and 60 Hz line frequencies, which minimizes beating. The circuit utilizes a dual MOS-FET (Q104A and Q104B) connected in a series-shunt configuration to maintain the required high input impedance.

2) AC Amplifier. The ac amplifier uses a JFET-input operational amplifier (U108). The amplifier feedback network provides a gain of approximately 133 at the modulating frequency of 390 Hz, while maintaining a gain of one for amplifier (U108) dc offset voltages.

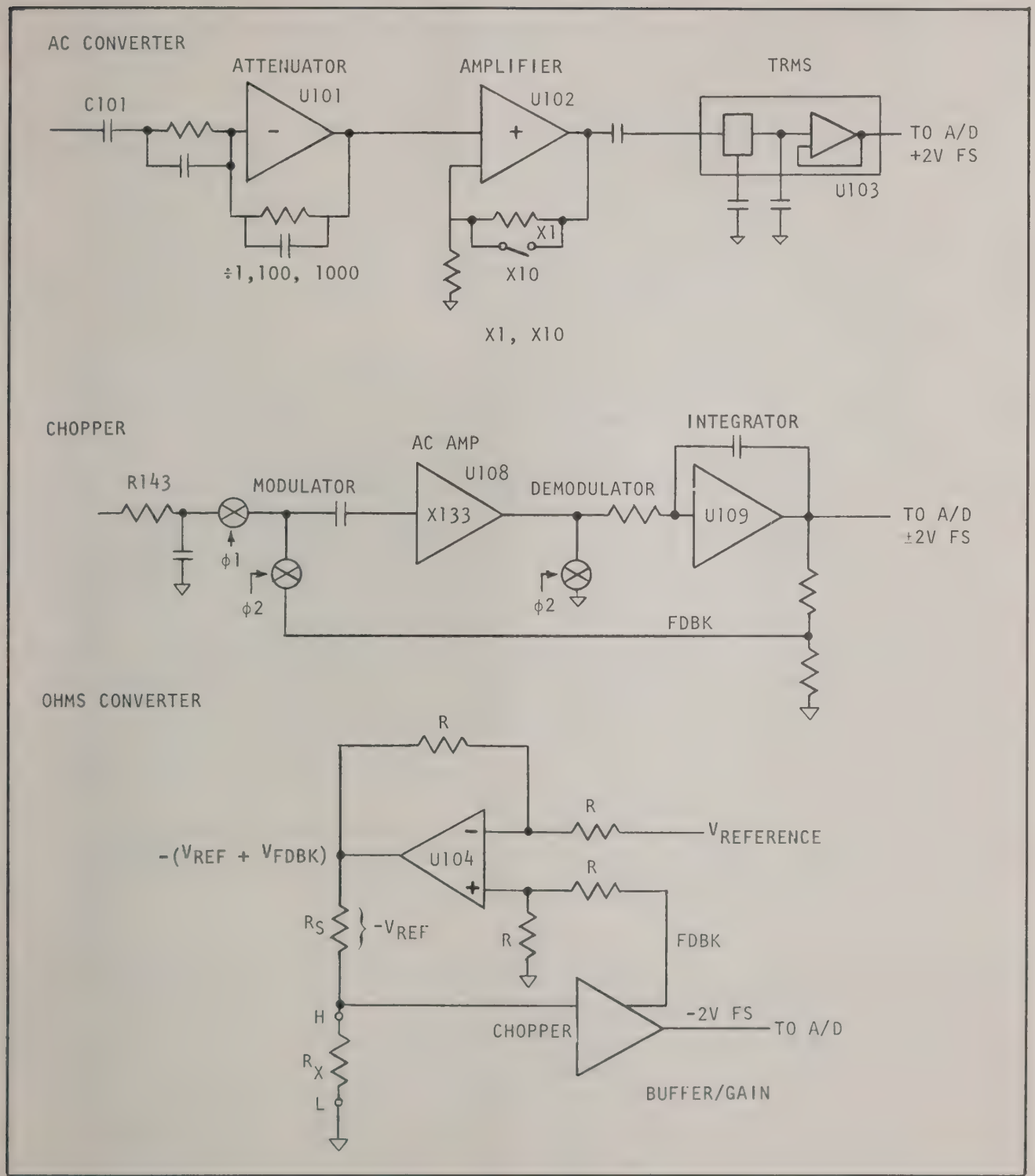


FIGURE 5-2. Simplified Signal Conditioning.

3) Demodulator Circuit. The demodulator is synchronized with the input modulator. A JFET (Q105) with low on-resistance is used to alternately attenuate and pass the signal present at the output of ac amplifier U108. This produces a "half-wave rectified" dc signal at the input of the integrator stage, that is inverted with respect to the chopper input signal.

4) DC Amplifier. Amplifier (U109) is connected as an integrator with an offset adjustment. U109 provides sufficient gain to bring the total open-loop dc gain to about one million. U109 drives the feedback divider network and the A/D converter, and provides the low output impedance necessary to drive the Analog Output. Feedback capacitor (C138) was selected to provide nominal settling time, while meeting NMR requirements. When the chopper is operating as a unity gain follower, the dc signal present at the output of U109 is the chopper feedback. This is the condition for the 2 VDC range and above. On the 200mV and 20mV ranges, where chopper gains of 10 and 100 are required, the resistive divider feeds back a portion of the output of U109 to provide the required gain.

5) Modulator-Demodulator Drive Circuit. CMOS inverters (U111A and U111F) provide opposite phase 0 to -15 volts square waves used to drive MOS-FET modulator transistors Q104A and Q104B. Inverter U111F also drives the demodulator JFET Q105. Resistors R118, R119 and R142, and capacitors C131 and C132 affect the rise and fall times of drive signals. R142 adjusts the rise and fall time of the drive signal to Q104A only, so that the total charge, both positive and negative, transferred to the input can be minimized. The frequency of the drive signal is determined by the clock circuit. Circuitry in U110 divides down a nominal clock frequency of 100 kHz to produce 390 Hz.

6) Adjustments and Input Protection. The front panel zero control (R203) permits adjustment of the chopper feedback to compensate for input thermal EMFs. It functions only on ranges where chopper gain is greater than one. A span of ±75µV is considered adequate, however, it is typical for R203 to provide a greater than 400µV change as it is turned end-to-end. The span is skewed by R128 to give best resolution in both DCV and Ω. Potentiometer R163 provides an internal X1 zero adjustment to compensate for amplifier offsets. Potentiometer R146 provides a calibration adjustment of the 200mV range (X10 gain configuration) and R147 adjusts the X100 gain used on the 20mV range. Chopper input resistor R143 limits the input current during momentary input overloads to 12mA, which is then absorbed by the chopper load resistance (R145 and/or R149) or the power supplies thru CR116 and CR117.

7) DC Current Measurements. As previously described, dc current measurements are made by placing the appropriate shunt resistor on the chopper input. A chopper gain of X10 is used for all current ranges except 20µA, which uses X100. The front panel zero control (R203) is functional for all dc current ranges.

5-5. OHMS CONVERSION. The ohms converter contains 2 sections: a floating current source and a high input impedance buffer/amplifier. The chopper employed as a buffer/amplifier in DCV is also used as the high impedance buffer/amplifier for Ω. Refer to paragraph 5-4, DC Signal Conditioning, for additional chopper theory.

a. Floating Current Source. The floating current source involves a differential amplifier (U107) driven by the A/D reference voltage and the chopper feedback voltage. This results in a constant voltage across the source resistance (= -V reference) which results in a constant current in the unknown resistance. One or more range resistors is always connected as the ohms source resistor (R_S) when ohms function is selected. Five different constant current levels are supplied by changing the value of R_S with the range pushbuttons. These levels are given in Table 5-4. For Ω, INPUT HI terminal is negative with respect to INPUT LO.

TABLE 5-4.
Ohms Conversion.

RANGE	R_S SOURCE RESISTANCE	CHOPPER GAIN	NOMINAL CURRENT
20	1k	x 100	1mA
200	1k	x 10	1mA
2k	1k	x 1	1mA
20k	10k	x 1	100µA
200k	100k	x 1	10µA
2000k	1M	x 1	1µA
20M	10M	x 1	0.1µA

b. Chopper. For ohms, the full scale chopper output is -2 volts. Gain is employed on the 20Ω and 200Ω ranges to give -2 VFS out with the nominal 1mA source current. The front panel zero control functions on these two ranges, allowing compensation for up to 200mΩ of lead resistance. Settling time is determined primarily by chopper input ($T = R_XC$) which results in 2 seconds to full scale on the 2000KΩ and 20MΩ ranges (.047µF x 2MΩ and .0047µF x 20MΩ).

c. Adjustments and Input Overload Protection. Two Ω source calibration adjustments are required. Potentiometer R162 compensates primarily for the tolerance of R_S (R158), while R159 compensates for ratio variations in the four gain resistors (R150 thru R153). The protection network at the source output isolates the amplifier from positive voltage overloads (Q103) and negative voltage overloads (CR120) applied to INPUT HI. Transistor Q107 clamps the source input during overload. The ratio of the base to emitter resistors on Q103 sets the open circuit voltage.

5-6. ANALOG OUTPUT. The rear panel ANALOG OUTPUT provides a ±2 volt full scale dc output signal (10K counts = 1V). The analog output signal is available on all instrument functions and ranges, with a negative polarity on ohms (Ω) and a positive polarity on AC. The output is unbuffered, supplied by either the chopper or the TRMS converter through 5KΩ effective resistance, with 1KΩ placed in the LO leg to prevent ground loops through INPUT LO.

5-7. CLOCK. A single chip CMOS oscillator/÷2^N package is used to generate the 100kHz A/D clock and the 390Hz chopper drive signals. The 100kHz 0V to 5V signal drives the A/D and battery pack directly. The 390Hz signal is level shifted to 0V to -15V and split into 2 phases for driving the chopper FETs. An RC adjustment (R142) provides chopper input bias current compensation. Balancing and guarding is employed to keep the drive signal out of the chopper AC amp stage.

5-8. A/D CONVERTER. The A/D converter operates on the dual slope principle. The timing is divided into 3 periods as described below.

a. Auto-Zero. The auto-zero period (A, Figure 5-3, Sheet 1) is 100 milliseconds in length, which corresponds to 10,000 clock pulses. During this period, the reference voltage (V_{REF}) is stored on capacitor C116. Capacitor C115 stores $V_{REF} + V_{OS1} - V_{OS2}$.

b. Signal -Integrate. The signal-integrate period (B, Figure 5-3, Sheet 1) is also 100 milliseconds in length. The A/D input is buffered and integrated by U105. Positive signals generate a negative-going ramp at the integrator output (Pin 14), while negative signals produce a positive-going ramp. The level of the integrated signal at the end of the signal-integrate period is proportional to the average of the applied signal during this period. Since signal integration continues for 100 milliseconds, the A/D converter exhibits high normal mode rejection for ac signals in multiples of 10 Hz, particularly the 50 and 60 Hz line frequencies.

c. Reference-Integrate. The reference-integrate period for a full scale input (C or D, Figure 5-3, Sheet 2) is 200 milliseconds, or 20,000 counts in length. During this period, the integrator is returned to baseline level by applying a reference voltage of a polarity opposite to that of the signal. A positive-going ramp is obtained by grounding the buffer input, while a negative-going ramp is produced by the integration of $2 \times V_{REF}$ (that is, V_{REF} + the voltage stored on C116). The time, or number of clock pulses, required for discharge is proportional to the signal input. Digital output is from latches within U106 which store the number of clock pulses required for the integrator to return to baseline level. The maximum count during this period is 20,000, which corresponds to a discharge period of 200 milliseconds, or full scale input. For an input of less than full scale, the A/D automatically reverts to auto-zero for that period of the 200 milliseconds remaining after return to baseline level. V_{REF} is provided by a divider across a temperature-compensated zener diode. Operational amplifier U104 provides the zener with a self-regulating bias.

5-9. DISPLAY. Five light-emitting diodes (LED) are driven by U203, which is a CMOS BCD-to-seven segment decoder/driver with bipolar current-sourcing outputs. Segment currents are limited to approximately 20 milliamperes peak by resistor network R202. The LED readout is a multiplexed, common-cathode configuration with Darlington array U202 sequentially sinking current from each digit. Blanking of the overrange digit is accomplished by gates U104C and U104D. U104A and U104B ensure that CMOS-compatible levels are maintained on U104D, regardless of the loading of U202. The minus polarity readout is blanked on ac voltage and resistance ranges by normally open contacts on the AC and Ω pushbuttons.

5-10. AC POWER SUPPLY. When the DMM is operated from ac line power, the power supply furnished +5, +15, and -15 volts from regulators VR101, VR102 and VR103, respectively. Full-wave rectified ac from bridge rectifiers CR103 and CR104 is filtered by capacitors C120, C123 and C125 and is applied to the linear voltage regulators.

5-11. MODEL 1788 BATTERY PACK. When the Model 1788 Battery Pack is installed in the DMM, S102 must be set to the BAT position to provide additional secondary voltage for battery charging. S102 also switches the input to VR101 from bridge rectifier CR103 to batteries BT301. Four 2-volt, 2.5 ampere-hour lead-acid cells supply approximately 9.8 volts at full charge. After six hours of use on battery power, the battery pack should be recharged to ensure long battery life.

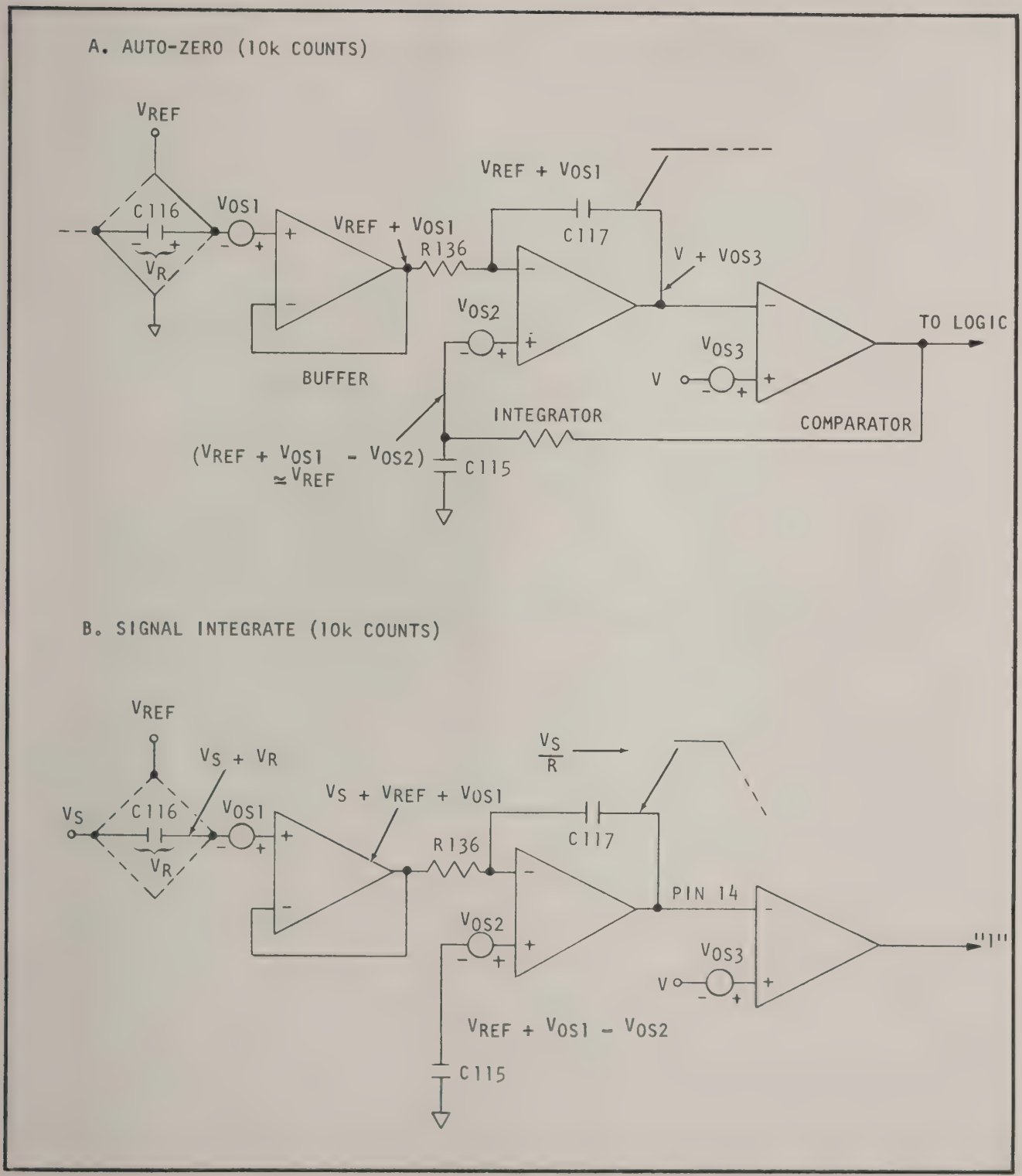
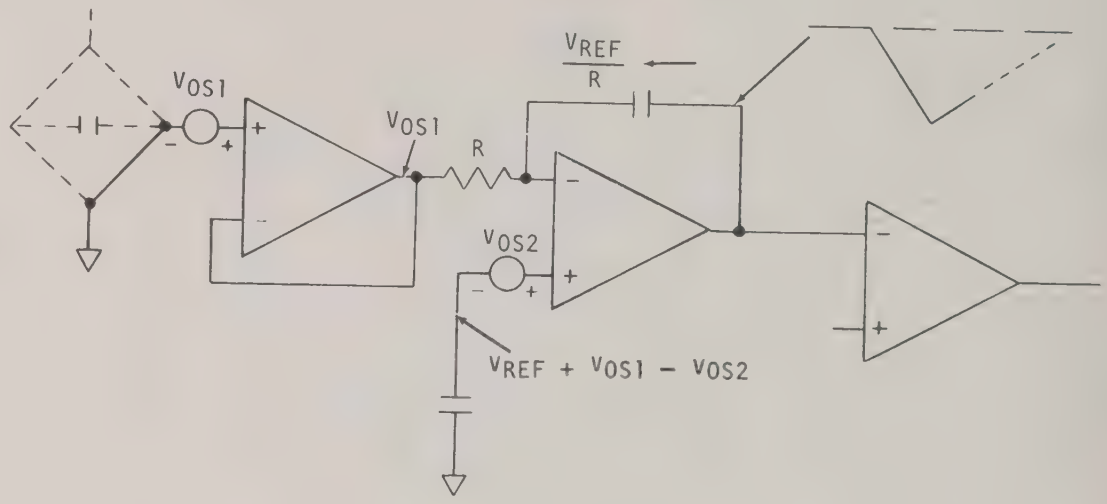


FIGURE 5-3. A/D Converter Function (Sheet 1 of 2)

C. NEGATIVE REFERENCE INTEGRATE (20k COUNTS AT FULL SCALE)
(POSITIVE INPUTS-TO A/D)



D. POSITIVE REFERENCE INTEGRATE (20k COUNTS AT FULL SCALE)
(NEGATIVE INPUTS TO A/D)

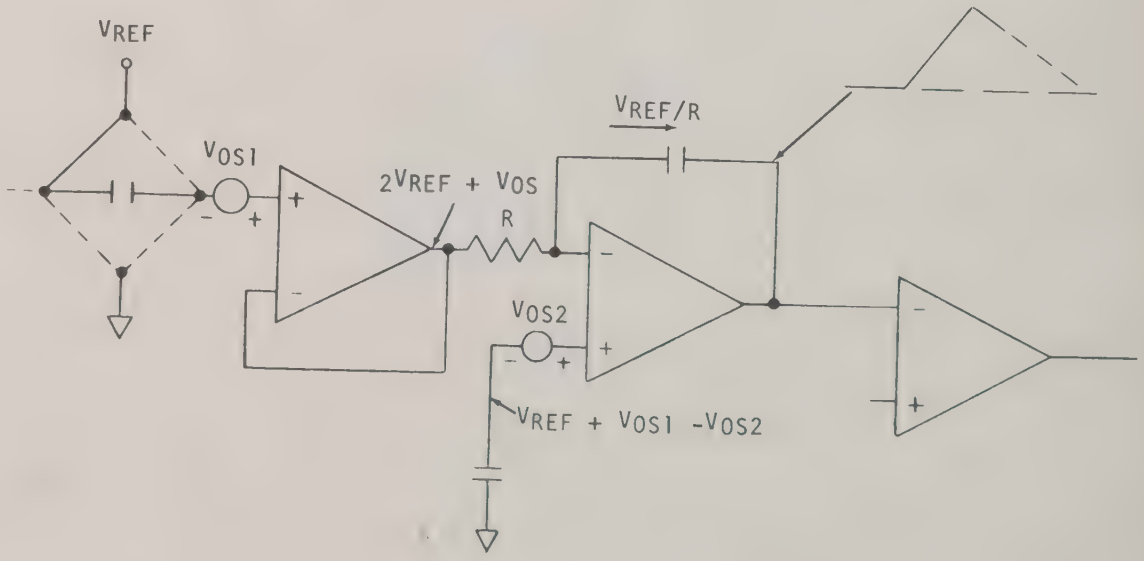


FIGURE 5-3. A/D Converter Function (Sheet 2 of 2)

a. Battery Charging Circuit. While the DMM is plugged into line power and the battery pack is installed, battery charging proceeds as follows:

1) Full-wave rectified voltage from CR103 is applied to the anode of Q301, which is an SCR which regulates charging voltage. When Q301 is triggered on by a sufficient gate-cathode voltage differential, the batteries receive charge. Charging continues as long as the bridge output voltage exceeds battery voltage by 1 volt or more. Resistor R304 limits charging current when recharging a set of completely discharged cells. A filtered positive output from CR104 (or T301) provides the necessary gate turn-on bias through R306 and diode CR301. Resistor R303 ensures proper high-temperature operation of Q301.

2) When the battery voltages reach the preset float voltages of 9.8 volts, zener VR301 conducts sufficient current to turn on Q302 and thus remove the gate trigger voltage from Q301. Float voltage is adjusted with R301. This is a factory adjustment which will normally not need field readjustment.

b. Battery Operation and Shutdown Circuit. The DMM operates as follows on battery power:

1) When the power is turned on, the batteries are connected to the input of VR101 to supply +5 volts for the logic, display and the clock circuit. The clock output is applied to the A/D converter as described in Paragraph 5-7, and U301 which is a divide-by-four binary counter. The outputs of U301 drive a dc-to-dc inverter which is synchronized to the A/D converter to filter out inverter noise. The 25 kHz operating frequency is optimal for the small transformer size and results in low switching losses. Blocking capacitors C301 and C302 protect Q307 and Q308 from damage if the drive is lost. Two half-wave rectifiers (CR304 and CR305) on the secondary of T301 provide rectified ac to filter capacitors C304 and C305, which provide power to +15 and -15 volt regulators VR102 and VR102, respectively.

2) To prevent permanent loss of battery capacity caused by deep discharge, a shutdown circuit stops operation on battery power when the battery voltage drops below approximately 7.2 volts. Shutdown is performed by micropower voltage detector U302. The open-collector output (U302, pin 4) saturates low and turns off pass transistor Q309 when the input voltage (at U302, pin 3) drops below 1.15 volts (typical). Resistor R314 provides sufficient hysteresis to prevent discharge from resuming when the battery voltage rises following disconnection of the load.

SECTION 6. MAINTENANCE.

6-1. GENERAL. This section contains information necessary to maintain the Model 177 DMM and Model 1788 Battery Pack. Adjustment/Calibration, Troubleshooting, Front Panel Zero Knob Removal and Replacement, and Fuse Replacement. Calibration should be performed yearly (every 12 months) or whenever Performance Verification (See Section 3) indicates that the Model 177 is out of specifications. If any step in the calibration procedure cannot be performed properly, refer to troubleshooting information in this section, or contact your Keithley representative or the factory as described in Section 3.

NOTE

Calibration should be performed by qualified personnel using accurate and reliable test equipment.

6-2. RECOMMENDED TEST EQUIPMENT. Recommended test equipment for calibration is listed in Table 6-1. Alternate test equipment may be used. However, the accuracy of the alternate test equipment must be at least 10 times better than the Model 177 specifications, or equal to Table 6-1 specifications.

TABLE 6-1.
Recommended Test Equipment For Calibration.

Item	Description	Specification	Mfr.	Model
A	DC Calibrator	0.1V, 1V, 10V, 100V, 1000V ±0.002% or 20μV	Fluke	343A
B	AC Calibrator	0.1V, 1V, 10V, 100V ±0.022%	H-P	745A
C	Decade Resistor	500Ω, 1.9KΩ, 190KΩ, ±0.01%	ESI	RS725
D	100Ω Per Step 4-Terminal Low Thermal Resistor	10:1 divider within 50 PMM (See Figure 3-1).	ESI	SR1010

6-3. ENVIRONMENTAL CONDITIONS. Calibration should be performed under laboratory conditions having an ambient temperature of 20° to 26°C (68° to 78°F), and a relative humidity of less than 80%. If the instrument has been subjected to temperatures outside of this range, or to higher humidity, allow one hour minimum for the instrument to stabilize at the specified environmental conditions before beginning the calibration procedure.

6-4. CALIBRATION PROCEDURE. Perform the following adjustments to calibrate the Model 177 DMM and restore its operation to specified limits.

a. Calibration Shield Installation. If the Model 1788 Battery Pack is installed in the instrument it must be removed and the calibration shield reinstalled before calibration.

WARNING

Disconnect the line cord before removing the case cover.

If the calibration sheild has been lost or misplaced, order Keithley Part Number 29473.

1) Turn off the power and disconnect the line cord. Remove four screws from the bottom of the case and separate the top cover from the bottom cover.

2) Push back the ground clip (shown in Figure 2-3) from the upper side of the battery pack and remove the battery pack from the spacers.

3) Calibration may be performed on battery power as long as the battery pack is sufficiently charged. Leave the battery pack plugged into the instrument, but set the battery pack behind the DMM on the bench or table. Ensure that LINE/BAT switch (S102) is in BAT position.

4) Set the calibration shield in place on the spacers. The shield should read correctly when viewed from the front of the instrument.

5) Slide the ground clip over the top of the calibration shield so that it contacts the upper surface of the shield.

6) If battery power is not to be used, plug in the line cord and position S102 to the LINE position if the battery pack has been disconnected.

b. Warm-Up. Turn the Model 177 on and allow a one hour warm-up time.

c. Calibration Instructions.

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death. Use an insulated tool when making adjustments.

1) Refer to Table 6-2 and perform the listed adjustments in the sequence indicated. Note that the step sequence is also indicated on the calibration shield by boxed numerals. The sequence must be followed exactly because the adjustments are interrelated and dependent on the preceeding steps. The step sequence (box numerals) is also shown on Schematic 29658E.

2) If the indicated adjustment cannot be made to obtain the specified reading, refer to Troubleshooting Information in this section.

TABLE 6-2.
Calibration Procedure

Step	Function	Range	Input	Adjustment Point	Desired Reading	Test Equipment
1	DC V	2 V	Short	R163	.0000/-.0000	None
2	DC V	2 V	Open	R142	.0000/-.0000	None
3	DC V	2 V	Short	R163	.0000/-.0000	None
4	DC V	2 V	Open	R142	.0000/-.0000	None
5	DC V	2 V	+1.9 V	R134	1.9000	DC Calibrator (A)
6	DC V	20 mV	Short	R203	.0000/-.0000	None
7	DC V	200 mV	+190 mV	R146	190.00	DC Calibrator
8	DC V	20 mV	+19 mV	R147	19.000	DC Calibrator and 10:1 Divider (D)
9	Ω	2 KΩ	500Ω	R162	.4999/.5000	Decade Resistor (C)
10	Ω	2 KΩ	1.9 KΩ	R159	1.9000	Decade Resistor
11	Ω	2 KΩ	500Ω	R162	.4999/.5000	Decade Resistor
12	Ω	2 KΩ	1.9 KΩ	R159	1.9000	Decade Resistor
13	Ω	200 KΩ	190 KΩ	R156	190.00	Decade Resistor
14	DC V	200 V	+190 V	R139	190.00	DC Calibrator
15	DC V	20 V	+19 V	R155	19.000	DC Calibrator
16	DC V	1000 V	+1000 V	R157	1000.0	DC Calibrator
17	AC V	2 V	.1 V @ 1kHz	R114	.1000	AC Calibrator (B)
18	AC V	2 V	1 V @ 1kHz	R113	1.0000	AC Calibrator
19	AC V	2 V	.1 V @ 1kHz	R114	.1000	AC Calibrator
20	AC V	2 V	1 V @ 1kHz	R113	1.0000	AC Calibrator
21	AC V	200 V	100 V @ 20 kHz	C102	100.00	AC Calibrator
22	AC V	2 V	1 V @ 20kHz	C103	1.0000	AC Calibrator

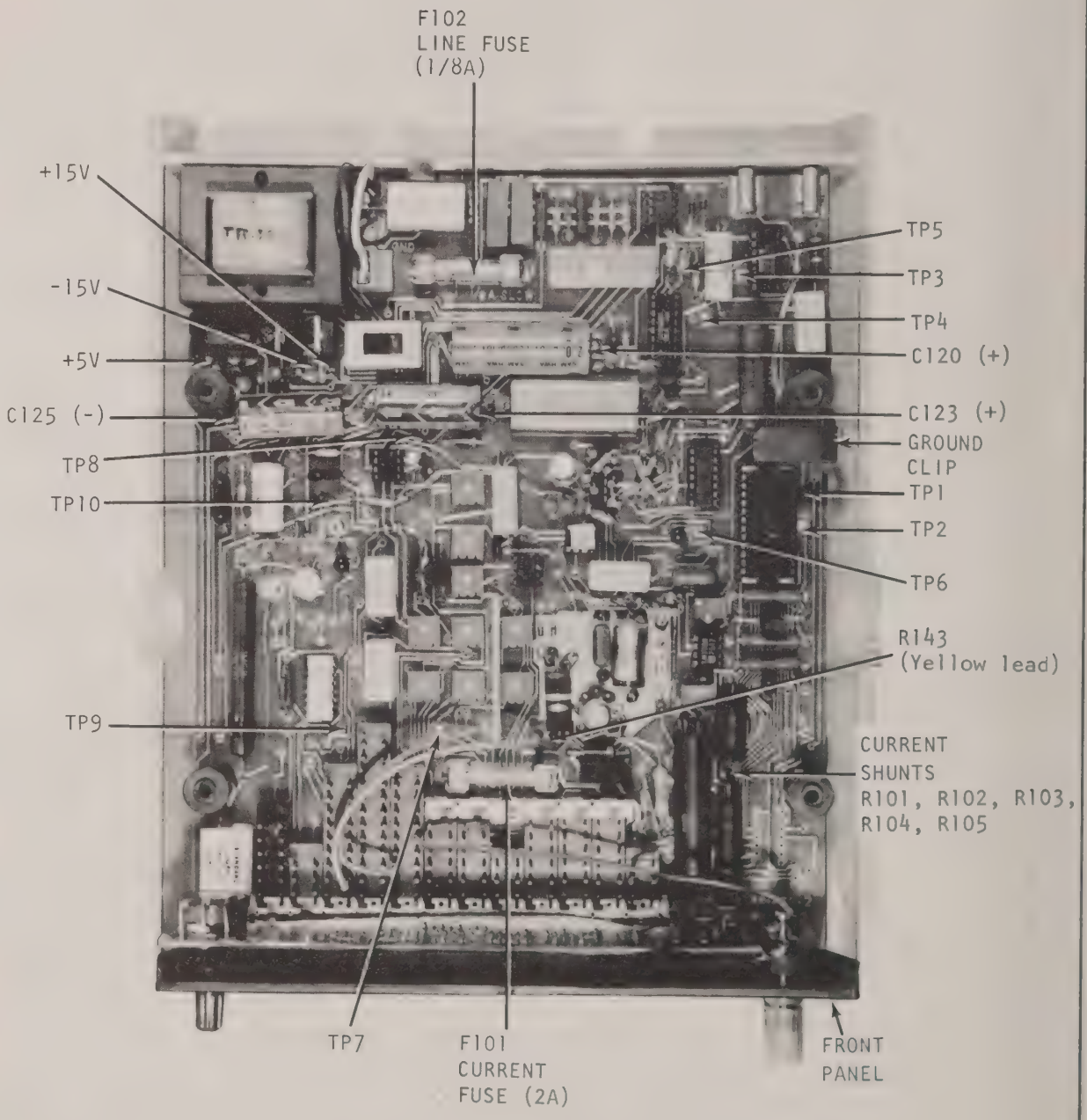


FIGURE 6-1. Test Point Locations.

6-5. TROUBLESHOOTING. The troubleshooting instructions contained in this section are intended for qualified personnel having a basic understanding of analog and digital electronic principles and components used in a precision electronic test instrument. Instructions have been written to assist in isolating the defective circuit or subcircuit. Isolation of the specific defective component has been left to the technician.

NOTE

For instruments that are still under warranty (less than 12 months since date of shipment), if the instrument's performance is outside of specifications at any point, contact your Keithley representative or the factory before attempting troubleshooting or repair, other than fuse replacement.

6-6. TROUBLESHOOTING PROCEDURE. This section contains tables listing step-by-step checks of the major DMM circuits described in Section 5, Theory of Operation. The following steps outline the use of these tables and provide instructions for preparing the DMM for troubleshooting. Read all of these steps carefully before troubleshooting the instrument.

a. Calibration Shield/Battery Pack Removal. If the Model 1788 Battery pack (or calibration shield) is installed, it must be removed to gain access to test points and circuit components for troubleshooting.

WARNING

Disconnect the line cord before removing the case cover.

1) Turn off power and disconnect the line cord. Remove four screws from the bottom of the case and separate the top cover from the bottom cover.

2) Push back the ground clip (shown in Figure 2-3) and remove either the calibration shield or battery pack from the spacers. If operation on battery power is to be checked, leave the battery pack plugged into the instrument, but set the battery pack behind the DMM on the bench or table.

b. Line Power. In general, start troubleshooting with Table 6-3, Line power checks, to verify that the power supplies are providing the correct voltages to the electronic components.

c. Battery Power. If trouble occurs on battery power only, or if battery operating time is substantially less than 6 hours after overnight charging, test the batteries and charging circuit per Table 6-4.

d. Proper operation of the A/D converter and display should be verified before troubleshooting the signal conditioning circuits. Check the A/D converter and display per Tables 6-6 and 6-5, respectively.

e. Problems with ac voltage or ac current ranges may involve the ac converter. Check this circuit per Table 6-7. If the problem is only on ac current ranges, see Step g, below.

f. Problems with dc voltage, dc current or resistance ranges may involve the chopper amplifier. Check this circuit per Table 6-8. After verifying chopper amplifier operation by completing step 1 thru 10 of Table 6-8, go to Table 6-9 if resistance measurements are erratic. If problem is only on dc current ranges, see Step g below.

NOTE

Dust, flux or other contamination will degrade performance on resistance and dc voltage ranges.

g. If problems occur with current readings, check the current shunts and related circuitry per Table 6-10. It should be noted that, since the current shunts are common to both ac and dc current, problems should exist on the same ac and dc current ranges if there is a fault in the current shunt circuitry.

h. All measurements are referenced to analog common (ground clip), unless otherwise noted in the Tables.

i. If a gross failure exists that indicates a possible blown fuse (line power, battery pack, or current fuse) refer to paragraph 6-8 for Fuse Replacement instructions.

WARNING

Some procedures in the following tables require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death.

TABLE 6-3.
Line Power Checks.

Step	Item/Component	Required Condition	Remarks
1	S101 line switch.	Must be set to 105-125V or 210-250V as appropriate.**	
2	S102 LINE/BAT switch.	Must be set to BAT for use with battery pack.	
3	F102 line fuse.	Continuity.	
4	P1007 line cord.	Plugged into live receptacle.	
5		Turn on power.	
6	+5V pad*.	+5 volts ±5%.	Output of VR101.
7	VR101, IN C120-2200µF (+).	+7 volts minimum.	Output of CR103, input to VR101.
8	+15V pad*.	+15 volts ±10%.	Output of VR102.
9	VR102 IN, C123-470µF (+).	+17.5 volts minimum.	Output of CR104, input to VR102.
10	-15V pad*.	-15 volts ±10%.	Output of VR103.
11	VR103 IN, C125-470µF (-).	-17.5 volts minimum.	Output of CR104, input to VR103. NOTE: Hot regulator may indicate shorted load.

* On main printed circuit board (see Figure 6-2).

** On optional line voltage units set to 90-110V or 180-220V as appropriate.

TABLE 6-4.
Battery Power Checks.

Step	Item/Component	Required Condition	Remarks
1		Check AC line power per Table 6-3.	
2		Turn off power.	
3	S102 LINE/BAT switch.	Move to BAT.	
4	P1007 line cord.	Plugged into live receptacle.	Charge circuit checks.
5	F301.	Remove fuse and connect ammeter to fuse clip. 0 to 500mA charging rate, varies with line voltage and battery state of charge.	No charge, see step 5A. Correct charging but short battery operating time, see step 6.
5A	BT301 Batteries.	Full charge is ≈9.8 volts over 4 cells. R301 adjusts charging rate (float voltage).	If voltage is low and adjustment of R301 does not start charging, see steps 7 and following. If voltage is low and adjustment of R301 does start charging, see Table 6-11 for adjustment of battery charge voltage.
6	Each battery cell voltage during charging.	1.5 - 3 volts for any cell.	High voltage or zero indicates damaged cell.
7	Q301 anode.	Full wave rectified voltage, 15 VDC nominal.	Output of CR103.
8	C304 +.	+17.5 volts minimum.	Output of CR104. Triggers Q301 gate thru R306 and CR301 unless Q302 is on.
9	Q302.	Should saturate only when battery approaches full charge.	
10	VR301.	8.2V zener.	
11		Unplug line cord & turn power on.	Discharge checks.
12	P1004 pin 8 or U301 pin 11.	100 kHz 5V square wave.	Clock input. If no input, see step 12A.
12A	VR101, IN.	+7 volts minimum.	Battery voltage input to VR101.
13	Q307 and Q308 base.	Square wave, ±0.7 volts at 25 kHz.	Output of U301, ÷ 4.
14	Q307, Q308 collector.	Must oscillate from saturation to twice battery voltage (≈19 volts) at 25 kHz.	Inverter.
15	C304, C305.	±17.5 volts minimum (±25 volts typical with fully charged bat.).	Inverter Output, input to VR102 and VR103.

TABLE 6-5.
Display.

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Any function or range, except OHMS.	
2	+5V Pad* or J1001, Pin 7.	+5 volts ± 5%.	If low, check per Table 6-3.
3	U202, pins 2, 6, 7, 9 and 13.	Digit drive. Low = enabled.	LED cathode.
4	U203, pins 1, 2, 6 and 7.	HI = enabled.	BCD input to U203 segment decoder/drive.
5	U203, pin 2.	Negative-going signal lasting for 200 clock pulses.	Leading digit suppression.
6	J1001, pin 2.	Polarity line (sign). HI = off LO = -	Polarity output is disabled on AC and Ω.
7	J1001, pin 4 J1002-Pins 1, 11 & 12	Appropriate DP line high (on).	Depress RANGE pushbuttons to check all DPs.

*On main printed circuit board. See Figure 6-2.

NOTE

If the display board has to be removed for troubleshooting or repair, the front panel ZERO knob will also have to be removed, Refer to Paragraph 6-7, Front Panel Zero Knob Removal and Replacement.

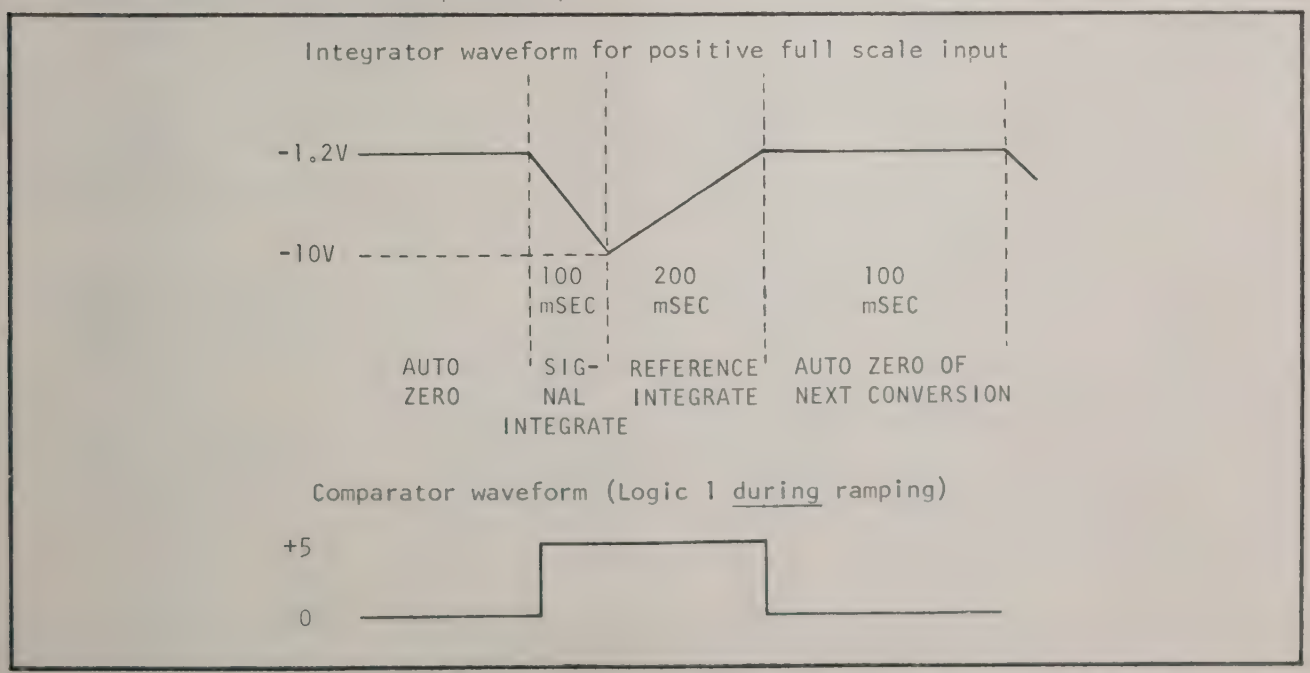


FIGURE 6-2. Integrator and Comparator Waveforms.

TABLE 6-6.
A/D Converter.

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 2 VDC range.	
2	Display.	.0000 ± 1 digit.	
3	TP1*.	0.0000 volts.	Input to U106, Chopper output.
4	TP2*.	+1.00 volt.	Reference output.
5		Short TP1 to TP2.	Connects reference output to U106 input.
6	Display.	1.0000 ± 2 digits.	If steps 4 and 6 are correct A/D converter is functioning properly. If not, continue with step 7.
7	TP4*.	0 to +5 volt square wave at 100 kHz ± 100 Hz.	Clock input to U106.
8	TP3*.	+1.0 ± 0.1 volts.	Stored autozero voltage.
9	U105, pin 11.	+1.0 ± 0.1 volts.	Σ-node voltage to integrator in U105.
10	U105, pin 14.	-1.2 ± 0.2 volts.	U105 integrator output voltage.
11	U105, pin 13.	+ 1 volt.	U105 buffer input.
12	U105, pin 9.	+ 1 volt.	U105 buffer output.
13	External voltage source.	Apply + 1.9000 volts.	Calibration point.
14	Display.	1.9000 ± 1 digit.	If different, check U106 input.
15	TP1.	1.9000 volt.	Input to U106.
16	U105, pin 14.	Waveform per Figure 6-3.	Integrator output.
17	U105, pin 2.	Waveform per Figure 6-3, during ramping of integrator.	Comparator output.

* On main printed circuit board, see Figure 6-2.

TABLE 6-7.
AC CONVERTER.

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 2 VAC range.	NOTE: Full scale input on all ranges should produce ≈2 volts rms output at TP8*.
2	External voltage source.	Apply 1 volt rms at 1 kHz.	Calibrated input.
3	TP10*	.99 volts rms nominal.	Output of U101 and feedback components R108 and C103 (nominal gain .99).
4	TP8*	.993 volts rms nominal.	Output of U102. (Q102 on, nominal gain 1.003).
5	U103 Pin 6 or TP1*	+1 volt.	Output of U103. Gain of U103 adjusted to provide +1 Vdc output for 1 Vac (1/2-scale) input.
6	External voltage source.	Select 20 VAC range. Apply 10 volts rms at 1 kHz.	Gain check of U101 and U102. Nominally, .0099 (U101) and 10.03 (U102).
7	TP10	.099 volts rms nominal.	Output of U101 and feedback components R109, C104 and Q101 (on).
8	TP8	.993 volts rms nominal.	Output of U102 (Q102 off).
9	External voltage source.	Select 1000 VAC range. Apply 1000V rms at 1 kHz.	Calibrated input. Check gain of U101 (nominal .00099).
10	TP10	.99 volts rms nominal.	Output of U101 and feedback components K101, R110 and C105 (K101 (Closed).
11	External voltage source.	Select 200 VAC range. Apply 100 v rms at 20 kHz.	Calibrated input.
12	Display.	100.00 nominal.	High frequency response (compensation C102, C103, C104).
13	External voltage source.	Select 2 VAC range. Apply 1 volt rms at 20 kHz.	Calibrated input.
14	Display.	1.0000 nominal.	High frequency response. (Compensation C102, C103).
15	External voltage source.	Select 1000 VAC range. Apply 1000 volts rms at 20 kHz.	
16	Display.	1000.0 ± nominal.	High frequency response. (Compensation C102, C103, C105)
17	External voltage source.	Select 2 VAC range. Apply 1 volt rms at 45 Hz.	
18	Display.	1.0000 V ± nominal.	Low frequency response. C101, C106, C107, C108, C109.

TABLE 6-8.
DC Attenuation and Chopper Amplifier.

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 20 mVDC range. Short input and adjust F.P. Zero for ±.0000 on display.	NOTE: Insufficient zero adjustment may indicate leaky FET switches in Chopper Amplifier Circuit.
2	TP5, TP6*.	≃ -7.5 volts DC (on DMM).	Chopper Drive. Signals are actually 0 to -15 square waves at 390 Hz. A steady zero volt or -15 volt signal indicates a problem in the chopper drive or clock circuitry.
3	External voltage source.	Apply + 19 mV.	Calibrated input.
4	R143 (yellow wire side)*.	+ 19mV.	Input to chopper amplifier ÷1 attenuation (range resistors).
5	TP1*.	+ 1.9 volts.	Input to U106, chopper output (x 100 gain).
6	External voltage source.	Select 200 mVDC range. Apply + 190 millivolts.	Calibrated input.
7	R143.	+ 190 mV.	Input to chopper amplifier ÷1 attenuation.
8	TP1.	+ 1.9 volts.	Input to U106, chopper output (x10 gain).
9	External voltage source.	Select 2 VDC range. Apply + 1.9 volts.	Calibrated input.
10	R143, TP1.	+ 1.9 volts.	÷1 attenuation, x1 chopper gain.
11	External voltage source.	Select 20 VDC range. Apply +19 volts.	Calibrated input.
12	R143.	+1.9 volts.	÷10 attenuation (range resistors).
13	External voltage source.	Select 200 VDC range. Apply +190 volts.	Calibrated input.
14	R143.	+1.9 volts.	÷ 100 attenuation (range resistors).
15	External voltage source.	Select 1000 (1200) VDC range. Apply +1000 volts.	Calibrated input.
16	R143.	+1 volt.	÷1000 attenuation (range resistors).

* On main printed circuit board, see Figure 6-2.

TABLE 6-9.
Ohms Source and Resistors.

Step	Item/Component	Required Condition	Remarks
1		Check chopper amplifier operation per Table 6-7, steps 1 thru 10.	
2		Select 2 KΩ range. Short Input.	
3	Display.	.0000 ±1 digit.	
4	TP9*	-1 volt approximately.	Inverted reference voltage plus calibrated offset of U107.
5	INPUT HI to LO.	Remove short and connect ammeter from INPUT HI to LO. Source Current should be approximately 1mA, HI Terminal negative.	If incorrect, check R158 and switching to INPUT HI and chopper amplifier.
6	INPUT HI to LO.	Remove ammeter and measure open circuit voltage. Voltage must be -2 to -5 volts.	HI negative with respect to LO. Display should be blinking, indicating overrange.
7	1.9KΩ resistor.	Apply to INPUT.	Calibrated resistance.
8	Display.	1.9000 ± 12 digits.	Subtract test lead resistance from reading. Checks accuracy of R158 and feedback loop to U107.
9	19 KΩ resistor.	Apply to INPUT. Select 20 KΩ range.	Calibrated resistance.
10	Display.	19.000 ± 12 digits.	Source resistors: R158, R154 (8.975 KΩ), R157 (wiper).
11	190 KΩ resistor.	Apply to INPUT. Select 200 KΩ range.	Calibrated resistance.
12	Display.	190.00 ± 12 digits.	Source resistors: R158, R157 R156 (wiper), R154 (89.75 KΩ, 8.975 KΩ).
13	1900 KΩ resistor.	Apply to INPUT. Select 2000 KΩ range.	Calibrated resistance.
14	Display.	1900.0 ± 12 digits.	Source resistors: R158, R157, R156, R155 (wiper), R154 (all except 8.975MΩ).
15	10 MΩ resistor.	Apply to INPUT. Select 20 MΩ range.	Calibrated resistance.
16	Display.	10.000 ± 12 digits. NOTE: Reference loading by the ohms source does not affect Ω readout since A/D converter is ratiometric.	Source resistors: all Ω range resistors. NOTE: To conveniently measure the resistance of all Ω range resistors, turn power off, set all function switches out and measure resistance INPUT HI to LO.

TABLE 6-10.
Current Shunts.

Step	Item/Component	Required Condition	Remarks
1	F101	Continuity.	
2	R101, R102, R103, R104, R105	Correct shunt value for specified range. See schematic.	Apply a known 1/2-scale current and measure voltage across shunt.
3		Turn on power. Select DCA and 200 µA range.	
4	External voltage source.	0 to 3 volts.	Clamping must occur at ±2 volts.

TABLE 6-11.
Adjustment of Battery Charge Voltage.

Step	Item/Component	Required Condition	Remarks
1		Instrument off.	
2	R301	Turn full CCW (maximum charge rate).	
3	BT301	Monitor battery voltage for > 9.8V.	Fully charged cells require several minutes to reach this level. Discharged cells require several hours. ⚠ CAUTION: Charging to > 10V for longer than 30 minutes will reduce battery life.
4	R301	When cells reach 9.8V, turn DMM on and adjust to maintain 9.8V across BT301.	

6-7. FRONT PANEL ZERO KNOB REMOVAL AND REPLACEMENT. The front panel zero knob will have to be removed if either the front panel or display board is to be removed. To remove the knob, proceed as follows:

a. Carefully remove the end-cap (shown in Figure 6-3) using a thin-bladed instrument.

b. Loosen the slotted screw and remove the knob from the shaft.

c. Take care not to damage or lose either the end-cap or knob. These items provide protection against electrical shock and must be installed when the instrument input is floating.

WARNING

The ZERO poteniometer shaft is electrically connected to INPUT LO. Maintain INPUT LO at ground potenital while the ZERO knob or its cap is removed to prevent an electrical shock hazard.

d. To replace the knob, reverse the above procedure. Do not substitute any other knob. If the knob or its cap is lost or damaged, order only Keithley part number KN-41-1 as a replacement.

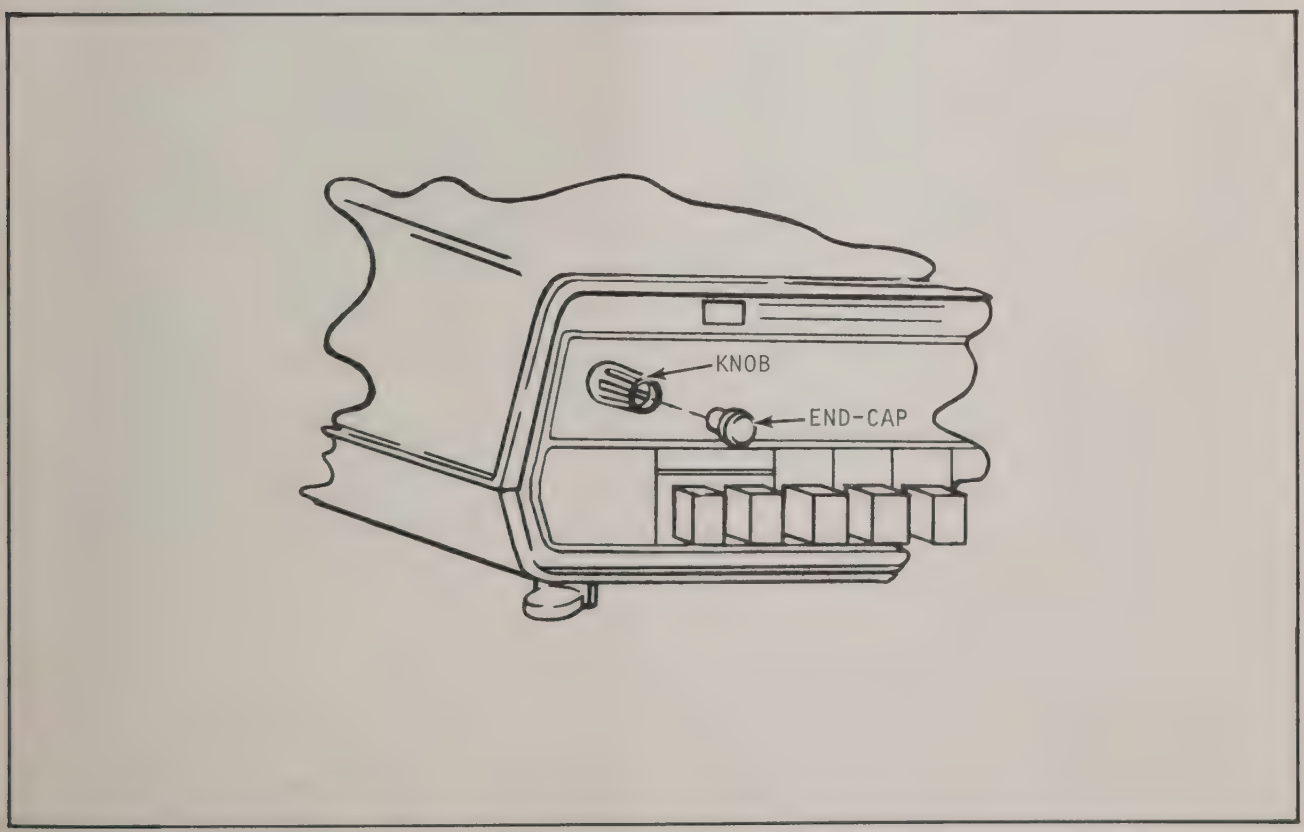


FIGURE 6-3. Front Panel Zero Knob Removal.

6-8. FUSE REPLACEMENT. All fuses are located internally in the Model 177. To replace a fuse, proceed as follows:

WARNING

Disconnect the line cord before removing the case cover.

a. Turn off power and disconnect the line cord.

b. Turn the DMM bottom side up and loosen the four screws in the bottom cover. These screws are held captive by rubber O-rings.

c. Hold the top and bottom covers together to prevent their separation and turn the DMM over to normal position.

d. Lift off the top cover.

CAUTION

Do not install fuses with higher ratings than specified. Instrument damage may occur.

e. Replacement of Battery Pack Fuse F301.

1) Leave the Battery Pack in place and connected.

2) Remove F301, shown in Figure 2-3, and replace it with a 2A, 250V, 3AG fuse. (Keithley part number FU-13).

f. Replacement of Line Power Fuse F102.

1) Once the top cover is removed, F102 is accessible without removing any other components.

2) Remove F102, shown in Figure 6-1, and replace it with a 2A, 250V, 3AG SLO-BLO fuse (Keithley part number FU-20) for standard line voltage units. Optional line voltage units with 90-110V and 190-210V ranges, use a 3/16A, 250V 3AG SLO-BLO fuse (Keithley part number FU-29).

g. Replacement of Current Fuse F101.

1) Lift the calibration cover, or Battery Pack, off of the spacers to gain access to the current fuse.

2) Remove F101, shown in Figure 6-1, and replace it with a 2A, 250V, 3AG fuse (Keithley part number FU-13).

3) Replace calibration shield, or Battery pack, on the spacers. Be sure that the ground clip, shown in Figure 6-1, is positioned on the top side of the shield or battery pack.

h. Replace the top cover.

SECTION 7. REPLACEABLE PARTS.

7-1. GENERAL. This section contains information for ordering replacement parts. Panels and covers are shown separately on Figure 7-1. The Replaceable Parts List is arranged in alphabetical order of the Circuit Designations of the components. A cross-reference list of manufacturers, containing their addresses, is given in Table 7-2.

7-2. ORDERING INFORMATION. To place an order or to obtain information concerning replacement parts, contact your Keithley representative or the Factory. See the inside front cover for addresses. When ordering, include the following information:

a. Instrument Model Number.

b. Instrument Serial Number.

c. Part Description.

d. Circuit Designation (if applicable).

e. Keithley Part Number.

7-3. FACTORY SERVICE. If the instrument is to be returned to the factory for service, please complete the Service Form which follows this section and return it with the instrument.

7-4. SCHEMATICS.

a. Model 177 4-1/2 Digit Multimeter: Schematic No. 29658E (Page 7-12).

b. Model 1788 Battery Pack: Schematic No. 29659C (Page 7-13).

7-5. COMPONENT LAYOUTS.

a. Model 177 PC-476 Component Layout No. 29474D (Page 7-15).

b. Display Board PC-475 Component Layout No. 29652C (Page 7-14).

c. Model 1788 Battery Pack PC-451 Component Layout No. 29007C (Page 7-13).

7-6. MAINTENANCE KIT. A Maintenance Kit is available that contains a complement of spare parts that will maintain up to ten Model 177 DMMs. Specify Part Number 29966 when ordering. A list of the kit parts is given in Table 7-1.

TABLE 7-1.
MODEL 177 MAINTENANCE KIT

QTY.	KEITHLEY PART NUMBER	SCHEMATIC NUMBER
2	DD-16	DS202, 3, 4, 5
1	DD-17	DS201
5	FU-13	F101
2	FU-20	F102
1	IC-93	VR101
1	IC-102*	U201
1	IC-139*	U111
1	IC-168*	U203
1	IC-169	U202
1	IC-197*	U110
1	IC-203	U107, 109
1	IC-205	U108
1	KN-41-1	Front Panel Zero
1	LSI-11	U106
1	LSI-12	U105
1	RL-56	K101
1	TF-80	R126
1	TG-77	Q101, 102, 105
1	TG-93	Q103
1	TG-94*	Q104

*Anti-Static Protection & Handling Required.

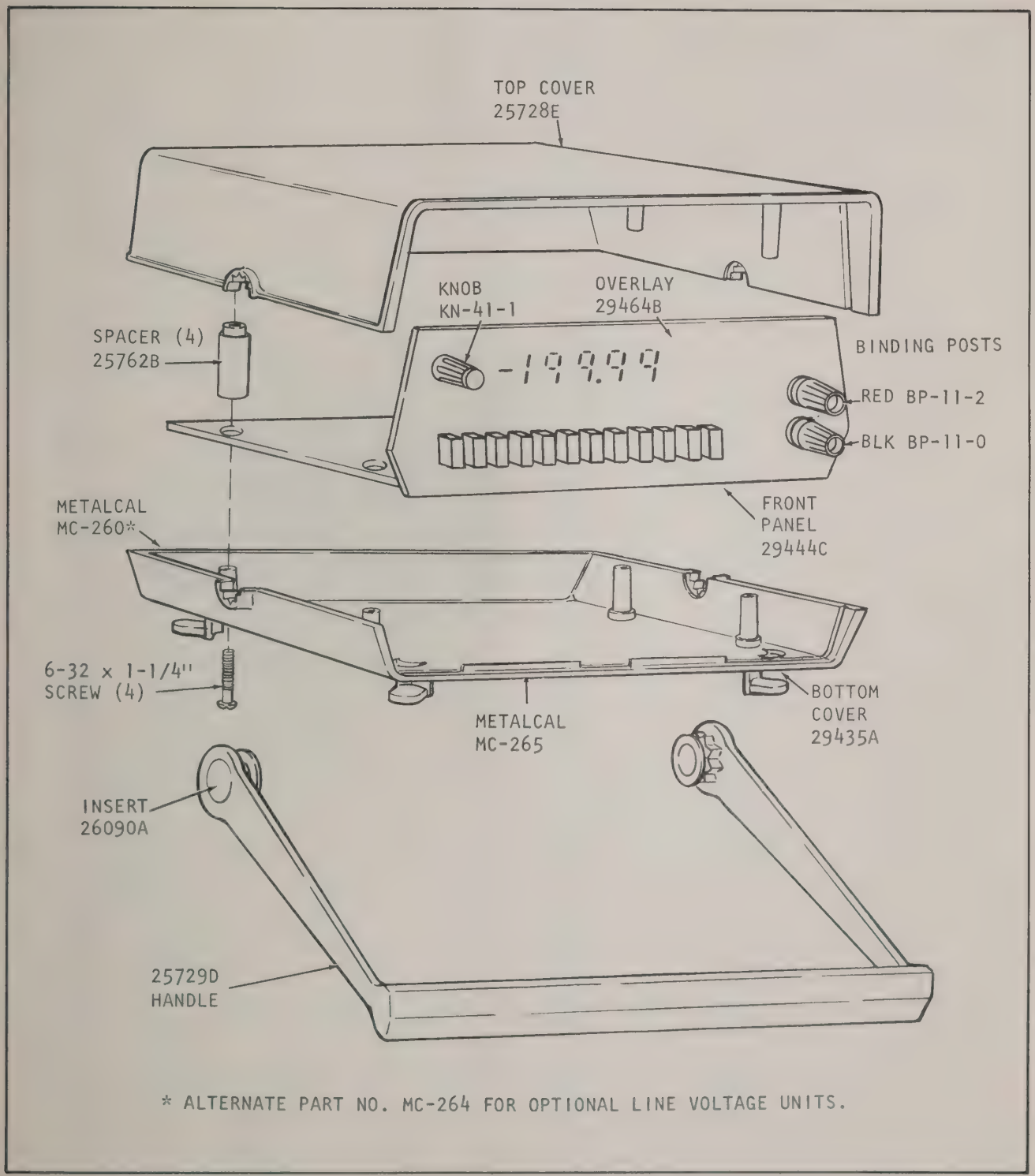


FIGURE 7-1. Covers and Panels.

TABLE 7-2.
Cross-Reference of Manufacturers.

MFR. CODE	NAME AND ADDRESS	FED. SUPPLY CODE
A-B	Allen-Bradley Corp. Milwaukee, WI 53204	01121
A-D	Analog Devices Inc. Norwood, MA 02026	24355
ACI	American Components, Inc. Conshohocken, PA 19423	14298
A-P	A-P Products, Inc. Painsville, Ohio	
AMP	Amphenol Broadview, IL 60153	02660
BEC	Beckman Inst. Inc. Fullerton, CA 92634	73138
BRN	Bourns, Inc. Riverside, CA 92507	80294
BUS	Bussman Mfg. Div. St. Louis, MO 63017	71400
C-I	Components, Inc. Biddeford, ME 04005	06751
C-W	Continential-Wirt Elec. Corp. Warminster, PA 18974	79727
CLB	Centralab Division Milwaukee, WI 53201	71590
COT	Coto-Coil Co., Inc. Providence, R.I.	
DLE	Dale Electronics, Inc. Columbus, NE 68601	91637
EDI	Electronic Devices, Inc. Yonkers, NY 10710	83701
EFJ	E.F. Johnson Co. Waseca, MN 56093	74970
F-I	Fairchild Inst. Corp. Mountain View, CA 94043	07263
G-E	General Electric Co. Syracuse, NY 13201	03508
G-I	General Instrument Corp. Newark, NJ 07104	72699
INT	Intersil Inc. Cupertino, CA 95014	32293
IRC	IRC Division Burlington, IA 52601	07716
K-I	Keithley Instruments, Inc. Cleveland, Ohio 44139	80164
L-F	Littlefuse, Inc. Des Plaines, IL 60016	75915
MEP	Mepco, Inc, Morristown, NJ	80031
MOL	Molex Downers Grove, IL 60515	27264
MOT	Motorola Semi Prod. Inc. Phoenix, AZ 85008	04713
NAT	National Semi Corp. Santa Clara, CA 95051	27014
NCI	National Components, Inc. West Palm Beach, FL	
NEL	Northern Engr. Labs. Burlington, WI 53105	00815
POT	Potter Co. Weston, Miss. 39191	13050
PRE	Precision Rectifier Hillside, NJ 07805	25007
RCA	RCA Corporation Moorestown, NJ 08050	02734
SHR	Sheridan Sales, Inc. Cincinnati, Ohio 45222	
SIE	Siemens Corp. Iselin, NJ 08830	25088
SIG	Signetics Corp. Sunnyvale, CA 94086	18324
HHS	H.H. Smith Brooklyn, NY 11207	83330
STD	Standard Condensor Chicago, IL	97419
SUP	Superior Electric Co. Bristol, CT. 06010	58474
T-I	Texas Instruments, Inc. Dallas, TX 75231	01295
TEP	Tepro Electric Corp. Rochester, NY 14606	02985
TRW	TRW Capacitor Div. Ogallala, NB 69153	84411

REPLACEABLE PARTS LIST

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
	BATTERIES (BT)					
	Model 1788 Battery Pack					
	"300" Series (Sch. 29659C-Pg. 7-13)					
BT301	Set of four "D" Cells, 8V	E2	---	*		
*	Lead-acid "D" cell, 2V, 2.5AH					
	(Used for BT301, four required)			G-E	GE0225	BA-33
	CAPACITORS (C)					
	"100" Series (Sch. 29658E-Pg. 7-15)					
	(PC-Board 476-Pg. 7-14)					
C101	0.1µF, 1000V, MPF	B3	4/E5	STD	M2W-F-0.1µF	C-285-.1
C102	.25-1.5pF, 2000V, Teflon Trimmer. .	B3	5/C5	EFJ	273-101	C-184
C103	.25-1.5pF, 2000V, Teflon Trimmer. .	D3	6/C5	EFJ	273-101	C-184
C104	110pF, 500VDC, ±1%, Silver Mica . .	D3	7/C5	G-I	RDM19FD112F03	C-278-110pF
C105	1100pF, 500VDC, ±1%, Silver Mica. .	D3	8/C5	G-I	RDM19FD111F03	C-278-1100pF
C106	33µF, 15V, ETT.	D4	9/C4	NCI	KNS336D015K	C-228-33
C107	33µF, 15V, ETT.	D4	10/C4	NCI	KNS336D015K	C-228-33
C108	1µF, 100V, ±10%, MPF.	E4	11/D4	POT	4309C105	C-294-1
C109	1µF, 100V, ±10%, MPF.	E3	12/C4	POT	4309C105	C-294-1
C110	NOT USED					
C111	2200pF, 500V, CerD.	G2	14/C2	CLB	831-25U0-222M	C-22-2200p
C112	100pF, 1000V, CerD.	D5	15/C3	CLB	DD-101	C-64-100pF
C113	NOT USED					
C114	NOT USED					
C115	1µF, 100V, ±10%, MPF.	H4	18/B1	POT	4309C105	C-294-1
C116	4µF, 100V, 10%, MPF	G3	19/B2	POT	0109-5432	C-294-4
C117	.22µF, 200VDC, ±10%, MPF.	H3	20/B2	TRW	22-200-10-X363UW	C-269-.22
C118	.12µF, 100V, 10%, MPF	G4	21/C2	POT	4039C	C-294-.12
C119	NOT USED					
C120	2200µF, 15V, EAL.	D7	23/B3	SHR	16FLA2200	C-290-2200
C121	4.7µF, 20V, ETT	E7	24/B5	NCI	KNS475A020K	C-179-4.7
C122	4.7µF, 20V, ETT	E7	25/B5	NCI	KNS475A020K	C-179-4.7
C123	470µF, 35V, EAL	D8	26/B4	NAC	35ELA470	C-289-470
C124	4.7µF, 20V, ETT	C5	27/C3	NCI	KNS475A020K	C-179-4.7
C125	470µF, 35V, EAL.	D8	28/B5	SHR	35ELA470	C-289-470
C126	4.7µF, 20V, ETT	C5	29/C3	NCI	KNS475A020K	C-179-4.7
C127	NOT USED					
C128	NOT USED					
C129	NOT USED					
C130	100pF, 1000V, CerD	A6	33/B2	CLB	DD-101	C-64-100pF
C131	100pF, 630V, Poly	C7	34/C2	SIE	B31360-A1101-H	C-252-100pF
C132	100pF, 630V, Poly	B7	35/A2	SIE	B31360-A1101-H	C-252-100pF
C133	.0047µF, 100V, Poly	B5	36/D3	POT	4100E-472K	C-301-.0047
C134	.12µF, 100V, 10%, MPF	B4	37/D3	POT	4039C	C-294-.12
C135	6800pF, 500VDC, ±5%, Poly.	C5	38/D3	CLB	CPR-22J	C-138-6800pF
C136	NOT USED					
C137	NOT USED					
C138	1µF, 100V, 10%, MPF.	E5	41/C3	NIC	DT200	C-294-2
C139	1µF, 100V, 10%, MPF.	C5	42/C3	POT	4309C105	C-294-1
C140	.047µF, 100V, Poly.	B5	43/D2	POT	4100B-473K	C-301-.047
	"200" Series (Sch. 29658E-Pg. 7-12)					
	(PC-Board 475-Pg. 7-14)					
C201	4.7µF, 20V, ETT	G-7	3/A3	NCI	KNS475A020K	C-179-4.7

CAPACITORS (C) (CON'T)
"300" Series (Sch. 29659C-Pg. 7-13)
(PC-Board 451-Pg. 7-13)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
C301	4.7µF, 20V, ETT	D3	3/E3	NCI	KNS475A020K	C-179-4.7
C302	4.7µF, 20V, ETT	D4	2/E3	NCI	KNS475A020K	C-179-4.7
C303	1.0µF, 250V, MPY	E4	4/E3	AMP	C280AE/A1M	C-256-1
C304	100µF, 35VC	B5	6/F4	SHR	35-ULA-100	C-295-100
C305	100µF, 35VC	B5	5/F3	SHR	35-ULA-100	C-295-100

DIODES (CR)
"100" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 476-Pg. 7-15)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
CR101	Bridge Rectifier, 50V, 5A, 4-Diode	B1	46/D3	EDI	PE05	RF-48
CR102	Silicon Rectifier	B1	47/D3	MOT	MR-501	RF-34
CR103	Bridge Rectifier, 100V, 2A	D7	48/B5	EDI	PD10	RF-36
CR104	Bridge Rectifier, 1A, 400V	D8	49/135	EDI	PF40	RF-46
CR105	NOT USED					
CR106	Rectifier, 75mA, 75V	C3	51/C5	T-I	1N4148	RF-28
CR107	Rectifier, 75mA, 75V	C3	52/C5	T-I	1N4148	RF-28
CR108	NOT USED					
CR109	NOT USED					
CR110	Rectifier, 75mA, 75V	H2	55/A2	T-I	1N4148	RF-28
CR111	Rectifier, 75mA, 75V	H3	56/A2	T-I	1N4148	RF-28
CR112	Rectifier, 75mA, 75V	H4	57/B2	T-I	1N4148	RF-28
CR113	Rectifier, 75mA, 75V	H4	58/B2	T-I	1N4148	RF-28
CR114	Rectifier, 75mA, 75V	B6	59/D3	T-I	1N4148	RF-28
CR115	Rectifier, 75mA, 75V	B6	60/D3	T-I	1N4148	RF-28
CR116	Rectifier, 75mA, 75V	E3	---	T-I	1N4148	RF-28
CR117	Rectifier, 75mA, 75V	F3	---	T-I	1N4148	RF-28
CR118	NOT USED					
CR119	NOT USED					
CR120	Rectifier, 1A, 800V	F1	65/B4	MOT	1N4006	RF-38

"300" Series (Sch. 29659C-Pg. 7-13)
(PC-Board 451-Pg. 7-13)

CR301	Rectifier, 75mA, 75V	B3	26/D4	T-I	1N4148	RF-28
CR302	Rectifier, 75mA, 75V	D4	28/E3	T-I	1N4148	RF-28
CR303	Rectifier, 75mA, 75V	D4	27/E3	T-I	1N4148	RF-28
CR304	Rectifier, 75mA, 75V	C5	30/F4	T-I	1N4148	RF-28
CR305	Rectifier, 75mA, 75V	C5	29/F4	T-I	1N4148	RF-28

DISPLAYS (DS)
"200" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 475-Pg. 7-14)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
DS201	±1 LED Digit	G7	5/C2	F-I	FND561	DD-17
DS202	7-Segment LED Digit	H7	6/C2	F-I	FND560	DD-16
DS203	7-Segment LED Digit	H7	7/C2	F-I	FND560	DD-16
DS204	7-Segment LED Digit	H7	8/D2	F-I	FND560	DD-16
DS205	7-Segment LED Digit	H7	9/D2	F-I	FND560	DD-16

FUSES (F)
"100" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 476-Pg. 7-15)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
F101	2A, 250V, 3AG, Quick.	B1	68/D3	L-F	312002	FU-13
F102	Slo-Blo, 1/8A, 250V, 3AG.	C8	69/B4	BUS	MDL	FU-20*

* Standard line voltages, optional line voltage units use 3/16A FU-29.

"300" Series (Sch. 29659C-Pg. 7-13)
(PC-Board 451-Pg. 7-17)

F301	2A, 250V, 3AG, Quick.	E1	13/C3	L-F	312002	FU-13

CONNECTORS (J)
"1000" Series (Sch. 29658E-Pg. 7-15)
(PC-Board 476-Pg. 7-14)

J1001	8-Pin Connector	F6	71/E5	A-P	929853-04	CS-356-4
J1002	12-Pin Connector.	G6/F8	72/E2	A-P	929853-06	CS-356-6
J1003	Female Connector.	C8	---	MOL	2139-3	CS-287-3
J1004	Connector Housing	A2	9/D5	MOL	2139-8	CS-287-8
J1005	Binding Post, Black	A2	---	HHS	DF-21-BC	BP-11-0
J1006	Binding Post, Red	A1	---	HHS	DF-21-BC	BP-11-2
J1007	NOT USED					
J1008	14-Pin Connector	K5,6	78/E2	T-I	C931402	SO-70
J1009	Contact	F5	79/A1, A2	K-I	Special	29316A

RELAYS (K)
"100" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 476-Pg. 7-15)

K101	5V, Reed Type	C3/E3	82/C5	COT	UF-40097	RL-56

CONNECTORS (P)
"1000" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 476-Pg. 7-15)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
P1001	8-Pin Connector	G6	11/A3	A-P	929838001-04	CS-355-4
P1002	12-Pin Connector.	G6/G8	12/F3	A-P	929838001-12	CS-355-6
P1003	Male, Connector	C8	73/A4	MOL	A-2391-3A	CS-288-3
P1004	Male, Connector	E6	74/A3	MOL	---	29467A
P1005	NOT USED					
P1006	NOT USED					
P1007	Line Cord	C8	---	K-I	SPECIAL	CO-9

TRANSISTORS (Q)
"100" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 476-Pg. 7-15)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
Q101	N-Chan, JFET.	C3	85/C5	INT	ITE4392	TG-77
Q102	N-Chan, JFET.	D4	86/C4	INT	ITE4392	TG-77
Q103	NPN, Case TO-5.	F1	87/C3	RCA	2N3439	TG-93
Q104(A-B)	Dual "P" Channel MOS Fet 8-PIN TO-77.	B5/C5	88/D3	G-I	955-004	TG-94
Q105	N-Chan JFET	D5	89/C3	INT	ITE4392	TG-77
Q106	PNP, Switch	A7	90/B2	F-I	2N5139	TG-66
Q107	NPN	G1	91/C2	F-I	2N3565	TG-39

TRANSISTORS (Q)
"300" Series (Sch. 29659C-Pg. 7-13)
(PC-Board 451-Pg. 7-13)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
Q301	Thyristor, SCR.	B2	38/C4	G-E	C106F1	TG-132
Q302	NPN Switch	B3	21/C3	MOT	2N3904	TG-47
Q303	PNP, Silicon, TO-92 Case.	D3	35/D4	MOT	2N3905	TG-53
Q304	NPN, Switch	D3	33/E4	MOT	2N3904	TG-47
Q305	NPN, Switch	C4	32/E4	MOT	2N3904	TG-47
Q306	PNP, Silicon, TO-92 Case.	C4	34/E4	MOT	2N3905	TG-53
Q307	NPN, Switch	D3	37/E3	MOT	2N3725	TG-131
Q308	NPN, Switch	D4	36/E3	MOT	2N3725	TG-131
Q309	PNP, Silicon.	C2	50/D3	MOT	MPS-U55	TG-133
Q310	PNP, Silicon, TO-92 Case.	C2	51/D3	MOT	2N3905	TG-53

RESISTORS (R)
"100" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 476-Pg. 7-15)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R101	.1Ω, 7.5W, WW	B2	94/E2	PRE	SM37244	R-262-.1
R102	.898Ω, ±.1%, 5W, WW	B2	95/E2	TEP	TS5	R-232-.898
R103	9Ω, .1%, 5W, WW	B2	96/D2	TEP	TS-1	R-252-9
R104	90Ω, .1%, 1/2W, MtF	C2	97/D2	DLE	MFF	R-169-90
R105	900Ω, .1%, 1/8W, MtF	C2	98/D2	DLE	MFF-1/8	R-168-900
R106	NOT USED					
R107	1M, 1000VRMS, 2W, MtF	C3	100/D5	ACI	CM-2	R-267-1M
R108	990KΩ, .1%, 1/8W, MtF	D3	101/C5	DLE	MMF-1/8	R-176-990K
R109	9.97KΩ, .1%, 1/8W, MtF.	D3	102/C5	DLE	MMF-1/8	R-176-9.97K
R110	991Ω, .1%, 1/8W, MtF	D3	103/C5	DLE	MMF-1/8	R-176-991
R111	90.3KΩ, .1%, 1/8W, MtF.	D4	104/C4	DLE	MMF-1/8	R-176-90.3K
R112	10KΩ, .1%, 1/8W, MtF.	C4	105/C4	DLE	MMF-1/8	R-176-10K
R113	500Ω, 0.5W, POT	E4	106/D4	BEC	72PMR-500	RP-97-500
R114	50KΩ, 10%, Cermet Trimmer	G2	107/D4	BEC	72PMR	RP-97-50K
R115	NOT USED					
R116	NOT USED					
R117	27KΩ, 5%, 1/4W, Comp	A7	110/C2	A-B	CB	R-76-27K
R118	4.32KΩ, 1%, 1/8W, MtF	B7	111/C3	IRC	CEA-TO-432K	R-88-4.32K
R119	4.99KΩ, 1%, 1/8W, MtF	B7	112/C2	IRC	CMF 1/10; T-1, 1%	R-88-4.99K
R120	NOT USED					
R121	3.9KΩ, 10%, 1/2W, Comp.	F5	114/A1	A-B	EB-3.9-10%	R-1-3.9K
R122	1KΩ, 10%, 1/4W, Comp.	F6	115/A1	A-B	CB	R-76-1K
R123	NOT USED					
R124	NOT USED					
R125(A-H)	Thick Film.	Several	118/C3	K-I	SPECIAL	TF-79
R126(A-K)	Thick Film.	Several	119/C3	K-I	SPECIAL	TF-80
R127	NOT USED					
R128	27KΩ, 10%, 1/4W, Comp.	G6	121/D5	A-B	CB	R-76-27K
R129	NOT USED					
R130	6.49KΩ, 1%, 1/8W, MtF	J1	123/A3	IRC	CEA-TO-6.49K	R-88-6.49K
R131	3.65KΩ, 1%, 1/8W, MtF	J1	124/A3	IRC	CEA-TO-3.65K	R-88-3.65K
R132	806Ω, 1%, 1/8W, MtF	H1	125/A3	IRC	CEA-TO-806	R-88-806
R133	2.15KΩ, 0.1% 1/10W, MtF.	H1	126/A3	TRW	MAR-5	R-263-2.15K
R134	50Ω, 3/4W, POT	H1	127/A3	BRN	3069P	RP-64-50
R135	402Ω, 0.1% 1/10W, MtF	H2	128/A3	TRW	MAR-5	R-263-402
R136	100KΩ, 1%, 1/8W, MtF.	H3	129/B2	IRC	CEA-TO-100K	R-88-100K
R137	Selected With DZ58	H1	130/A3	K-I	SPECIAL	PART OF 27699A
R138	33.2KΩ, ±1%, 1/8W, MtF.	F5	131/C4	IRC	CEA-TO-33.2K	R-88-33.2K
R139	50KΩ, 10%, Cermet Trimmer	D1	132/D3	BEC	72PMR	RP-97-50K
R140	47KΩ, 10%, 1/4W, Comp	A6	133/B3	MEP	CR25, 5%	R-76-47K
R141	22M, ±10% 1/4W, MtF	A6	134/B3	A-B	CB	R-76-22M

RESISTORS (R) (CON'T)
"100" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 476-Pg. 7-15)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R142	1KΩ, ±10%, 3/4W, POT.	B7	135/A3	BRN	3069P	RP-64-1K
R143	100KΩ, 10%, 2W, Comp.	B5	136/D3	A-B	HB	R-3-100K
R144	22KΩ, ±10%, 1/4W,	B5	137/D3	A-B	CB	R-76-22K
R145	922Ω, 0.1%, 1/4W, MtF.	E5	138/C4	TRW	MAR-7	R-264-922
R146	10KΩ, 0.5W, POT..	F5	139/C4	BEC	72PMR	RP-97-10K
R147	100Ω, 0.5W, POT	E5	140/C4	BEC	72PMR	RP-97-100
R148	8.95KΩ, 0.1%, 1/10W, MtF	F5	141/C4	TRW	MAR-5	R-263-8.95K
R149	100Ω, .1%, 1/10W, MtF	F6	142/C4	TRW	MAR-5	R-263-100
R150	998KΩ, .1%, 1/4W, MtF	G1	143/D2	TRW	MAR-7, T13	R-264-998K
R151	998KΩ, .1%, 1/4W, MtF	G1	144/D2	TRW	MAR-7, T13	R-264-998K
R152	998KΩ, .1%, 1/4W, MtF	G1	145/D2	TRW	MAR-7, T13	R-264-998K
R153	994KΩ, .1%, 1/4W, MtF	G2	146/D2	TRW	MAR-7, T13	R-264-994K
R154	Thick Film	D1	147/D3	K-I	SPECIAL	TF-78
R155	5KΩ, 10%, Cermet Trimmer.	D1	148/D4	BEC	72PMR	RP-97-5K
R156	500Ω, 10%, Cermet Trimmer	E1	149/D3	BEC	72PMR	RP-97-500
R157	50Ω, 10%, Cermet Trimmer.	E1	150/D4	BEC	72PMR	RP-97-50
R158	1KΩ, .1%, 1/10W, MtF.	F1	151/D4	TRW	MAR-5	R-263-1.0K
R159	10KΩ, 10%, Cermet Trimmer	G2	152/D2	BEC	89P	RP-89-10K
R160	NOT USED.					
R161	3.9M, 10%, 1/4W, Comp	F6	154/C4	A-B	CB	R-76-3.9M
R162	50KΩ, 10%, Cermet Trimmer	G2	155/C2	BEC	89P	RP-89-50K
R163	200KΩ, .5W, POT	E5	156/C4	BEC	72PMR-200K	RP-97-200K
R164	200KΩ, 1%, 1/8W, MtF.	G2	157/D2	IRC	CEA-T0-200K	R-88-200K
R165	100Ω, 1%, 1/8W, MtF	G2	158/C2	IRC	CEA-T0-100	R-88-100

"200" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 475-Pg. 7-14)

R201	Thick Film.	G8	14/C3	BRN	4310R 102-121	TF-82
R202	Thick Film.	J7	15/E3	DLE	LDP14-01-470G	TF-64
R203	Potentiometer	G6	16/A2	BRN	3856H	RP-117-50K

"300" Series (Sch. 29659C-Pg. 7-13)
(PC-Board 451-Pg. 7-13)

R301	20KΩ, 10%, Cermet Trimmer	C3	25/C3	BEC	72PMR	RP-97-20K
R302	330Ω, 10%, 1/4W, Comp	B3	20/C3	MEP	CR25, 5%	R-76-330
R303	1KΩ, 10%, 1/4W, Comp.	B3	21/D4	MEP	CR25, 5%	R-76-1K
R304	3.9KΩ, ±20%, 3W, WW	B2	24/D4	TEP	TS3	R-268-3.9K
R305	4.7KΩ, 10%, 1/4W, Comp.	B4	23/D3	MEP	CR25, 5%	R-76-4.7K
R306	3.3KΩ,10%, 1/4W, Comp	B4	22/C3	A-B	CB-332-10%	R-76-3.3K
R307	82Ω, 10%, 1/4W, Comp	D4	19/E3	MEP	CR25, 5%	R-76-82
R308	82Ω, 10%, 1/4W, Comp	D4	18/E3	MEP	CR25, 5%	R-76-82
R309	10Ω, 10%, 1/4W, Comp	B5	17/F4	A-B	CB-100-10%	R-76-10
R310	10Ω, 10%, 1/4W, Comp	B5	16/F4	A-B	CB-100-10%	R-76-10
R311	100KΩ, 1%, 1/8W, Comp	D2	44/E3	A-B	CB-104-10%	R-76-100K
R312	100KΩ, 1%, 1/8W, Comp	D2	45/E3	A-B	CB-104-10%	R-76-100K
R313	100KΩ, 1%, 1/8W, Comp	D2	43/E3	A-B	CB-104-10%	R-76-100K
R314	6.8M, 10%, 1/4W, Comp	D2	46/E3	A-B	CB-6J5R-10%	R-76-6.8M
R315	576KΩ, 1%, 1/8W, MtF	D2	48/E3	IRC	CEA-T0-576K	R-88-576K
R316	100KΩ, 1%, 1/8W, MtF	D2	47/E3	IRC	CEA-T0-100K	R-88-100K

SWITCHES (S)
"100" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 476-Pg. 7-15)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
S101	Line Selector	C7	161/A4	C-W	GG350PCDPOT	SW-318
S102	Line Battery	D7	162/B4	K-I	SPECIAL	SW-397
S103	12 Station Pushbutton	Several	163/E3,E5	K-I	SPECIAL	29434B

TRANSFORMERS (T)
"100" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 476-Pg. 7-15)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
T101	Transformer, Power	D6	165/A5	K-I	SPECIAL	TR-168 *
	* Standard line voltages, optional line voltage units use TR-169					
	"300" Series (Sch. 29659C-Pg. 7-13) (PC-Board 451-Pg. 7-17)					
T301	Transformer, Inverter	E3	39/F3	K-I	SPECIAL	TR-170

INTEGRATED CIRCUITS (U)
"100" Series (Sch. 29658E-Pg. 7-12)
(PC-Board 476-Pg. 7-15)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
U101	8-Pin Op-Amp JFET	C4	167/C5	T-I	TL081CL	IC-196
U102	BI-FET, Op-Amp.	D4	168/C4	NAT	LF351N	IC-176
U103	True RMS-TO-DC Converter.	E4	169/D5	A-D	AD536J	IC-172
U104	8-Pin Op-Amp DIP.	J1	170/A2	F-I	U6T7741393	IC-42
U105	4-1/2 Digit Analog-Processor.	H3	171/A2	INT	8052A	LSI-12
U106	4-1/2 Digit Logic-Processor	H4	172/C2	INT	7103A	LSI-11
U107	Linear Op-Amp 8-Pin	G1	173/C2	INT	LM308AN	IC-203
U108	J-FET Input Op-Amp.	C5	174/C3	MOT	LF355BN-Selected	IC-205
U109	Linear Op-Amp 8-Pin	D5	175/C3	INT	LM308AN	IC-203
U110	CMOS 14-Stage Binary Converter.	A6	176/B2	NAT	CD4060BCN	IC-197
U111	Six COS/MOS Hex Inverter.	A7	177/C2	RCA	CD4069B	IC-139
	"200" Series (Sch. 29658E-Pg. 7-12) (PC-Board 475-Pg. 7-14)					
U201(A-D)	4011 CMOS Unbuffered.	Several	18/E3	MOT	MC14011CP	IC-102
U202	Digit Driver.	G-7	19/E2	T-I	75492	IC-169
U203	Segment Drive	J-7	20/E3	MOT	4511	IC-168
	"300" Series (Sch. 29659C-Pg. 7-13) (Pc-Board 451-Pg. 7-13)					
U301	Dual D-Type Flip-Flop 14-Pin DIP.	C4	14/D3	RCA	CD4013AE	IC-103
U302	1.1V Micro-Power Detector	D2	49/E3	INT	ICL8211CPA-Selected	IC-177

VOLTAGE REGULATORS (VR)
"100" Series (Sch. 29658E-Pg. 7-12)
(Pc-Board 476-Pg. 7-15)

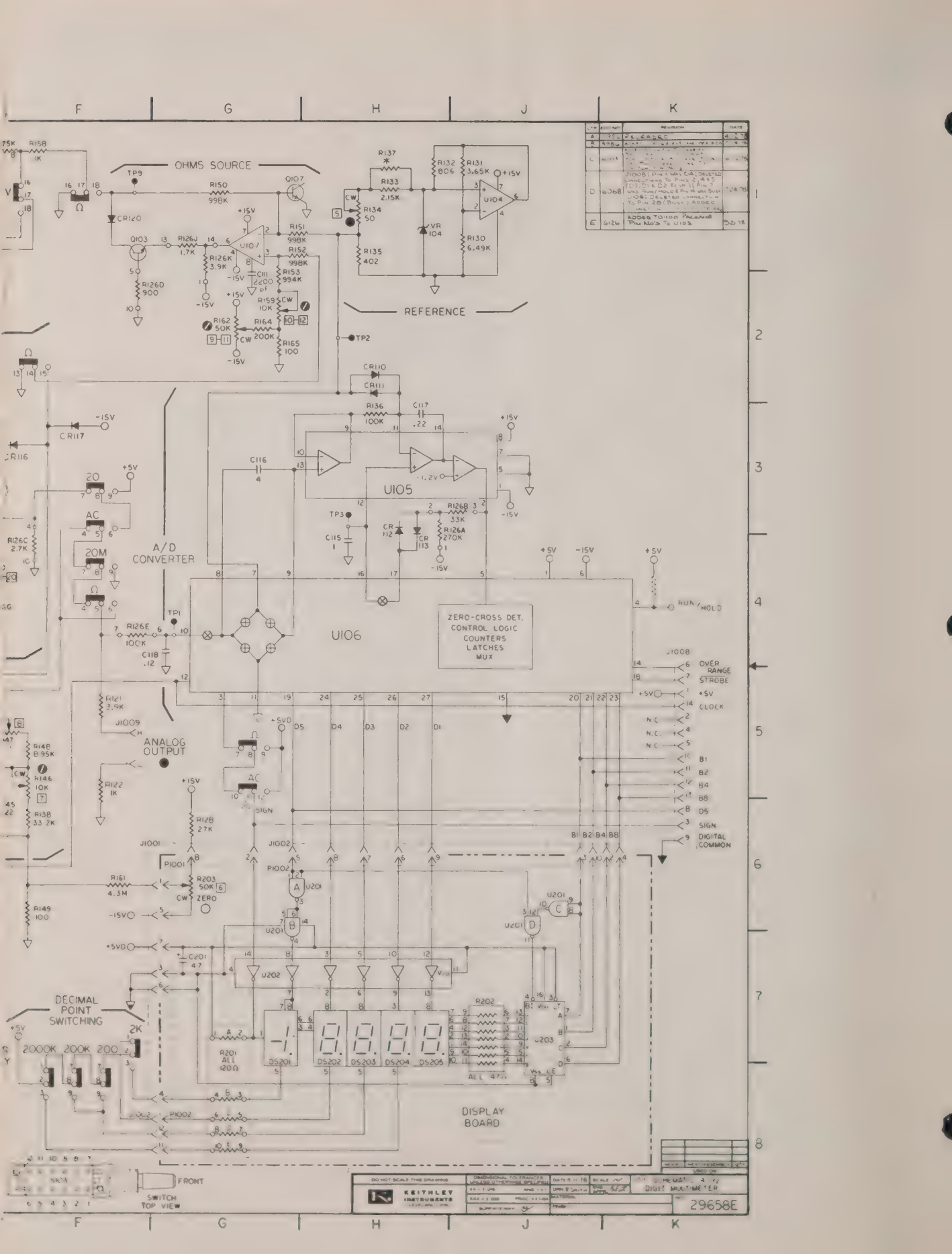
Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
VR101	+5V, 3-Term, TO-220	E7	180/B5	MOT	MC7805C1	IC-93
VR102	+15V, 500mA	E8	181/B5	F-I	78M15CU	IC-194
VR103	-15V, 500mA	E8	182/B5	SIG	78M15CU	IC-195
VR104	Selected DZ-58.	H1	183/A3	K-I	SPECIAL	27699A

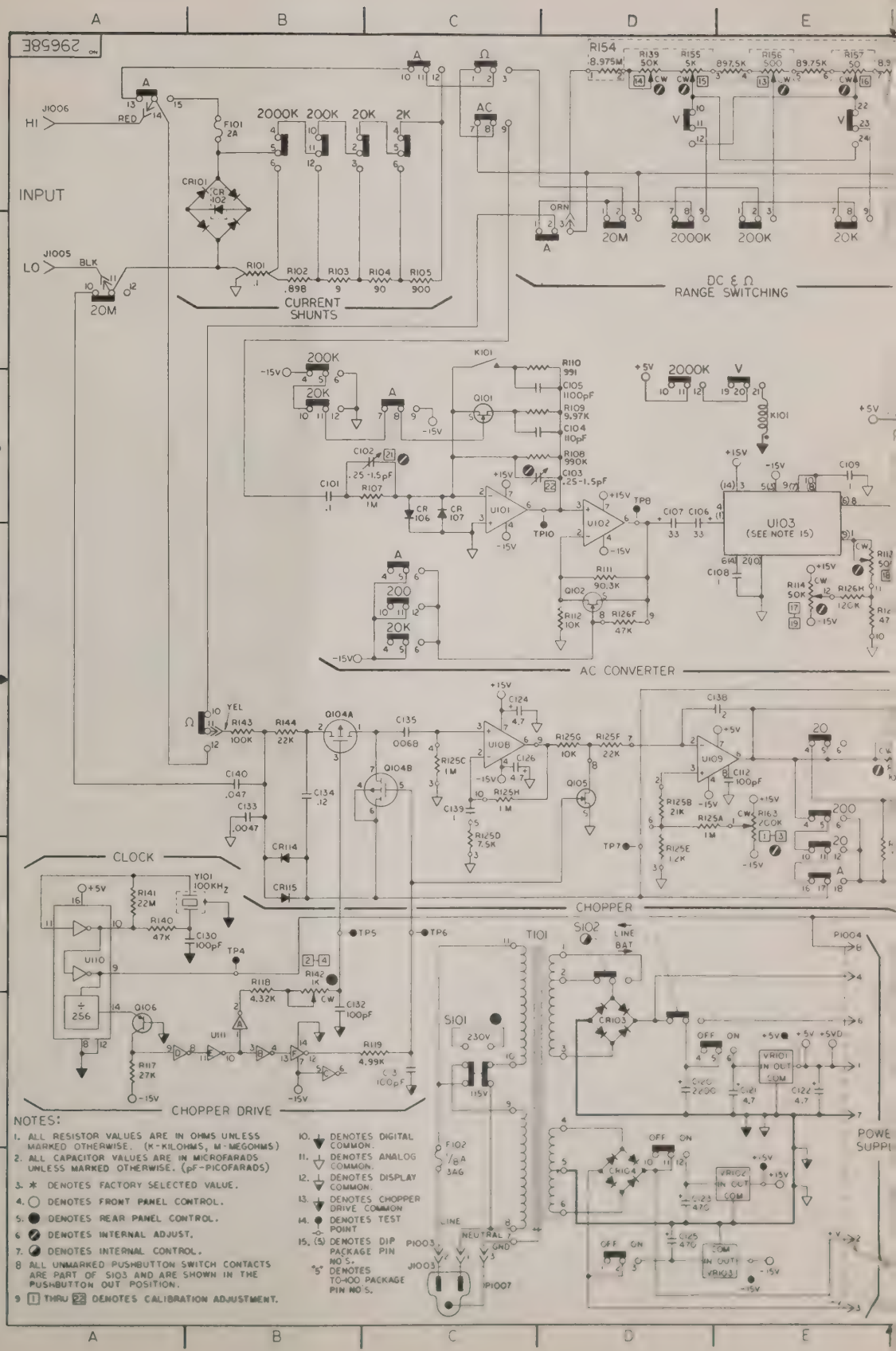
"300" Series (Sch. 29659C-Pg. 7-13)
(PC-Board 451-Pg. 7-13)

VR301	8.2Volt, Zener.	B3	10/C3	MOT	1N765A	DZ-61

CRYSTAL (Y)
"100" Series (Sch. 29658E-Pg. 7-15)
(PC-Board 476-Pg. 7-14)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
Y101	Quartz, ±0.01%, 100kHz	A6	186/B3	NEL	NE34PE	CR-8


OHMS SOURCE
REFERENCE
A/D CONVERTER
U105
U106
ZERO-CROSS DET.
CONTROL LOGIC
COUNTERS
LATCHES
MUX
ANALOG OUTPUT
DECIMAL POINT SWITCHING
DISPLAY BOARD
SWITCH TOP VIEW
FRONT
OVER RANGE
STROBE
CLOCK
SIGN
DIGITAL COMMON
RUN/HOLD
ZERO
KEITHLEY INSTRUMENTS
DIGIT MULTIMETER
29658E



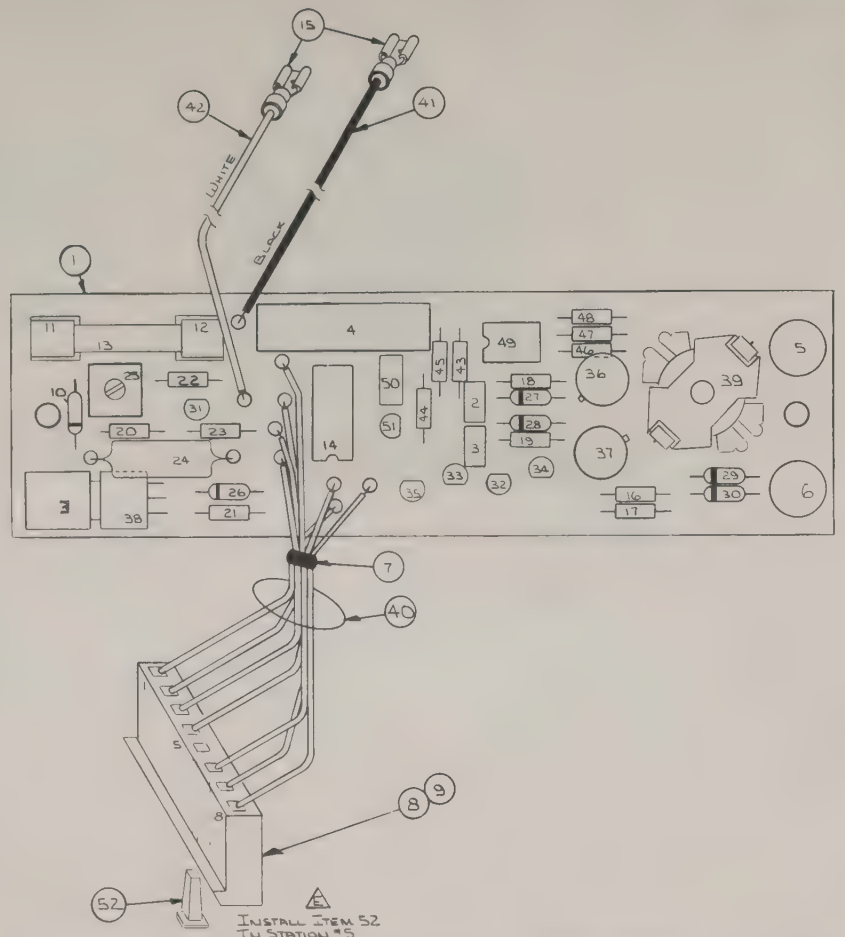
NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS, M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. * DENOTES FACTORY SELECTED VALUE.
4. ○ DENOTES FRONT PANEL CONTROL.
5. ● DENOTES REAR PANEL CONTROL.
6. ◐ DENOTES INTERNAL ADJUST.
7. ◪ DENOTES INTERNAL CONTROL.
8. ALL UNMARKED PUSHBUTTON SWITCH CONTACTS ARE PART OF S103 AND ARE SHOWN IN THE PUSHBUTTON OUT POSITION.
9. [1] THRU [22] DENOTES CALIBRATION ADJUSTMENT.
10. ▼ DENOTES DIGITAL COMMON.
11. ▽ DENOTES ANALOG COMMON.
12. ⏚ DENOTES DISPLAY COMMON.
13. ⏚ DENOTES CHOPPER DRIVE COMMON
14. ● DENOTES TEST POINT
15. (5) DENOTES DIP PACKAGE PIN NO'S. "5" DENOTES TO-100 PACKAGE PIN NO'S.

290070

ITEM	PART NO	SCHEM DESIG	ZONE
1	290056	MOUNTING PLATE	C2
2	C-79-4.7	C302	E3
3	"	C301	E3
4	C-256-1	C303	E3
5	C-295-100	C305	F3
6	"	C304	F4
7	CC-38-2	—	D4
8	CS-76	7 REQ'D	D5
9	CS-287-B	J1004	D5
10	SZ-61	VR301	C3
11	FH-12	—	C2
12	"	—	D3
13	FU-13	F301	C3
14	IC-103	U301	D3
15	LU-87	2 REQ'D	D2
16	R-76-10	R310	F4
17	"	R309	F4
18	R-76-82	R308	E3
19	"	R307	E3
20	R-76-330	R302	C3
21	R-76-1K	R303	D4
22	R-76-3.3K	R306	C3
23	R-76-4.7K	R305	D3
24	R-268-2.2	R304	D4
25	RP-91-20K	R301	C3
26	RF-28	CR301	D4
27	"	CR303	E3
28	"	CR302	E3
29	"	CR305	F4
30	"	CR304	F4
31	TG-47	Q302	C3
32	"	Q305	E4
33	"	Q304	E4
34	TG-53	Q306	E4
35	"	Q303	D4
36	TG-131	Q308	E3
37	"	Q307	E3
38	TG-132	Q301	C4
39	TR-170	T301	F3
40	(SEE WIRE LIST)	7 REQ'D	D4
41	SC-76-0	—	D2
42	SC-76-9	—	D2
43	R-76-100K	R313	E3
44	"	R311	E3
45	"	R312	E3
46	R-76-6.8M	R314	F3
47	" 88 100K	R316	E3
48	R-88-576K	R315	E3
49	IC-177	U302	E3
50	TG-133	Q309	D3
51	TG-53	Q310	D3
52	CS-345	—	C6

ZONE	LTR	ECO NO	REVISION	DATE
	B	5731	REVISED [illegible]	9-16-77
	C	5759	[illegible]	10-28-77
	D	5797	[illegible]	[illegible]
	E	5911	ADDED ITEM 52	3-7-78
	F	5930	[illegible]	4-7-78



1788		1
MODEL	NEXT ASSEMBLY	QTY
USED ON		

DO NOT SCALE THIS DRAWING

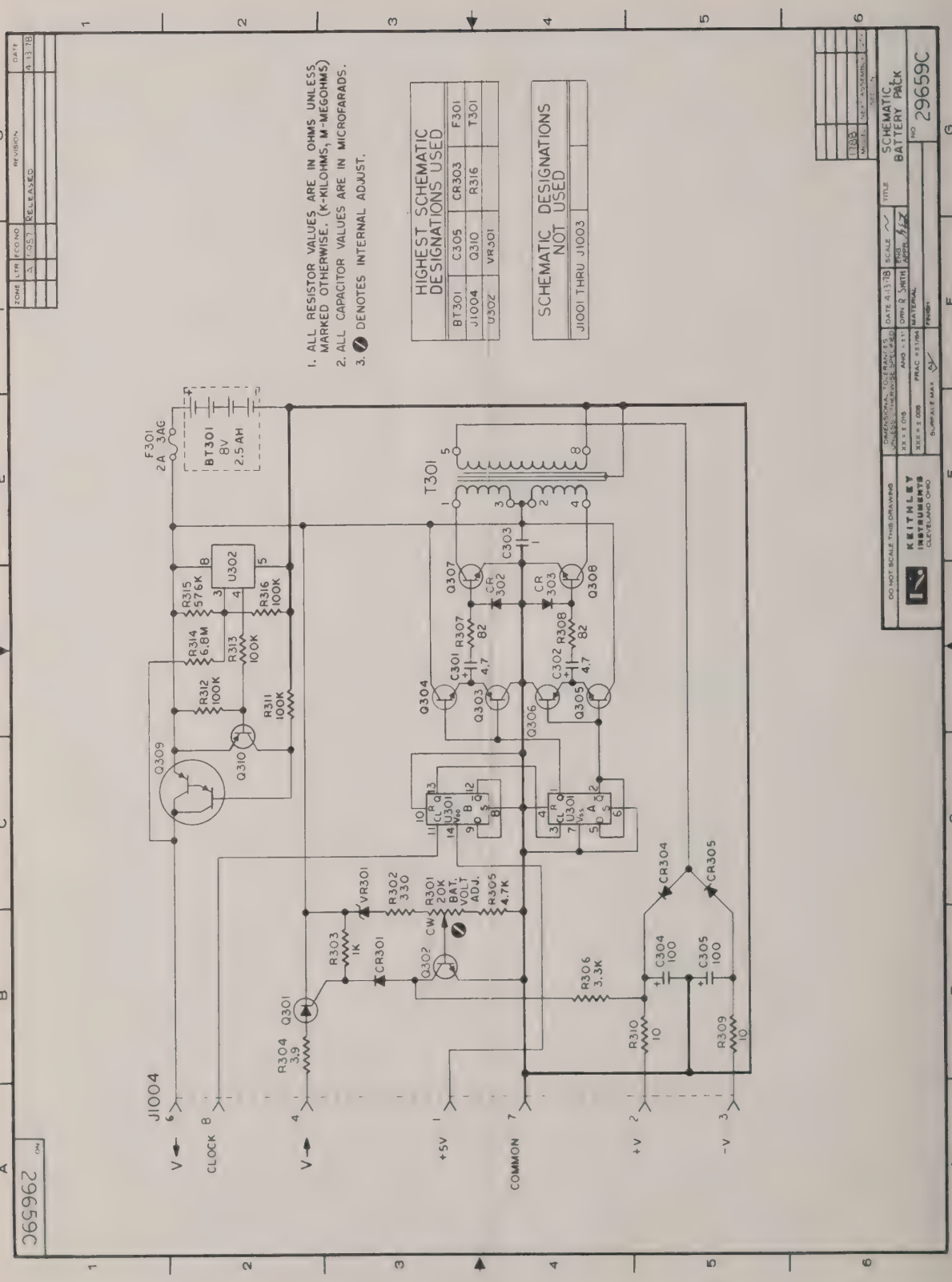
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX = ± .015 ANG = ±1°
XXX = ± .005 FRAC = ±1/64
SURFACE MAX 63

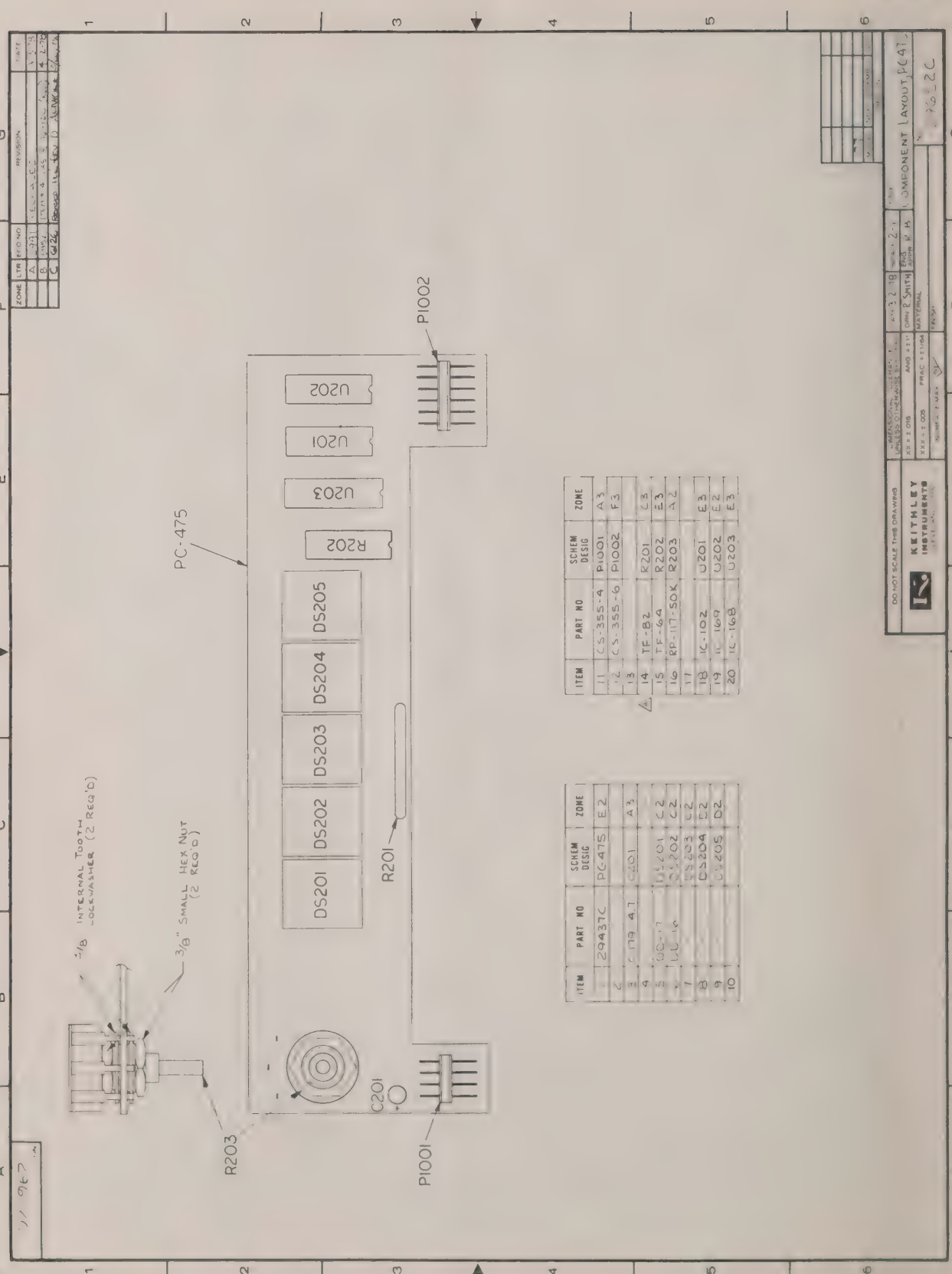
DATE 9-13-77 SCALE 2-1
DRN RB ENG APPR R.B.
MATERIAL
FINISH

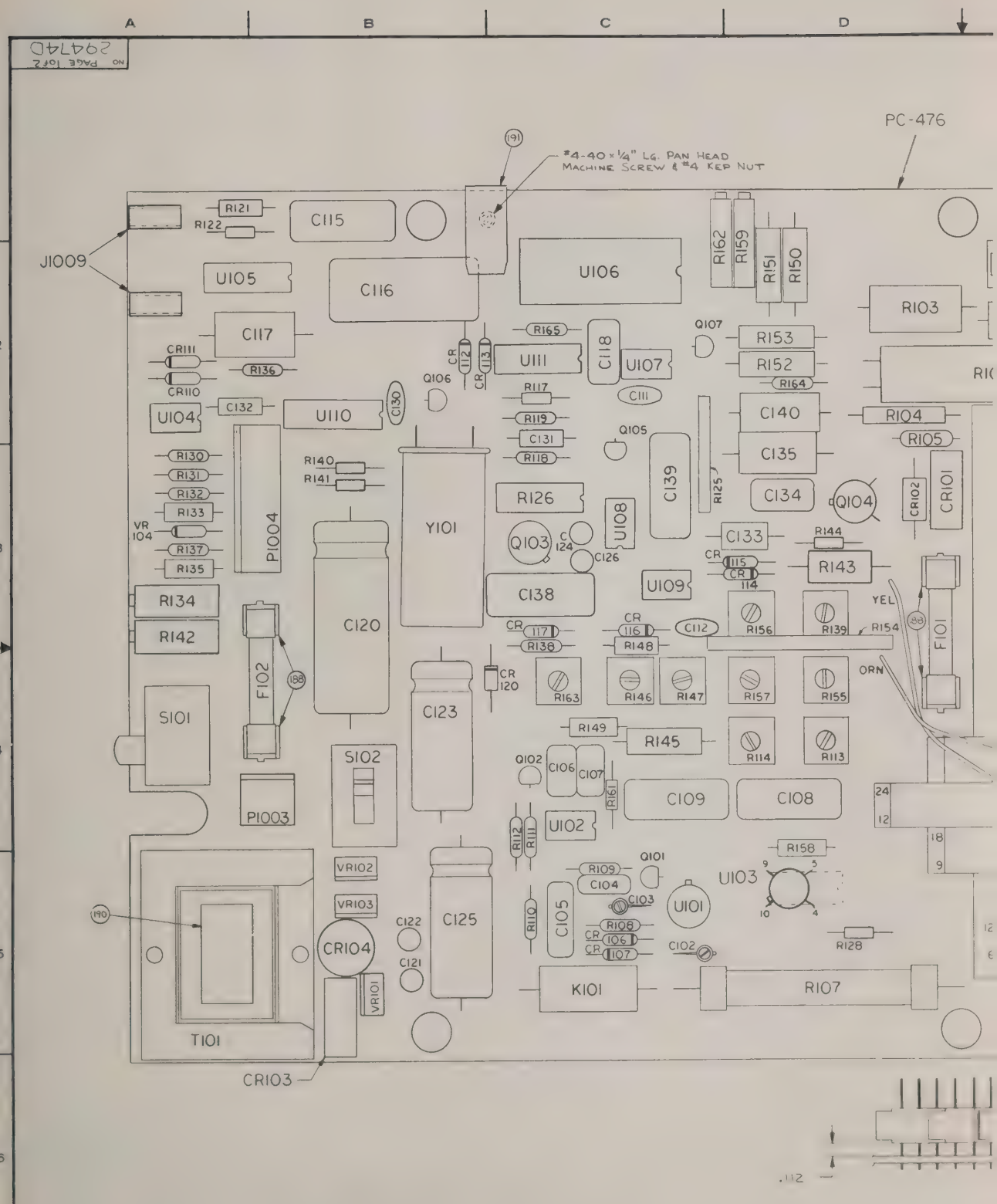
KEITHLEY INSTRUMENTS CLEVELAND OHIO

TITLE COMPONENT LAYOUT, PC-451

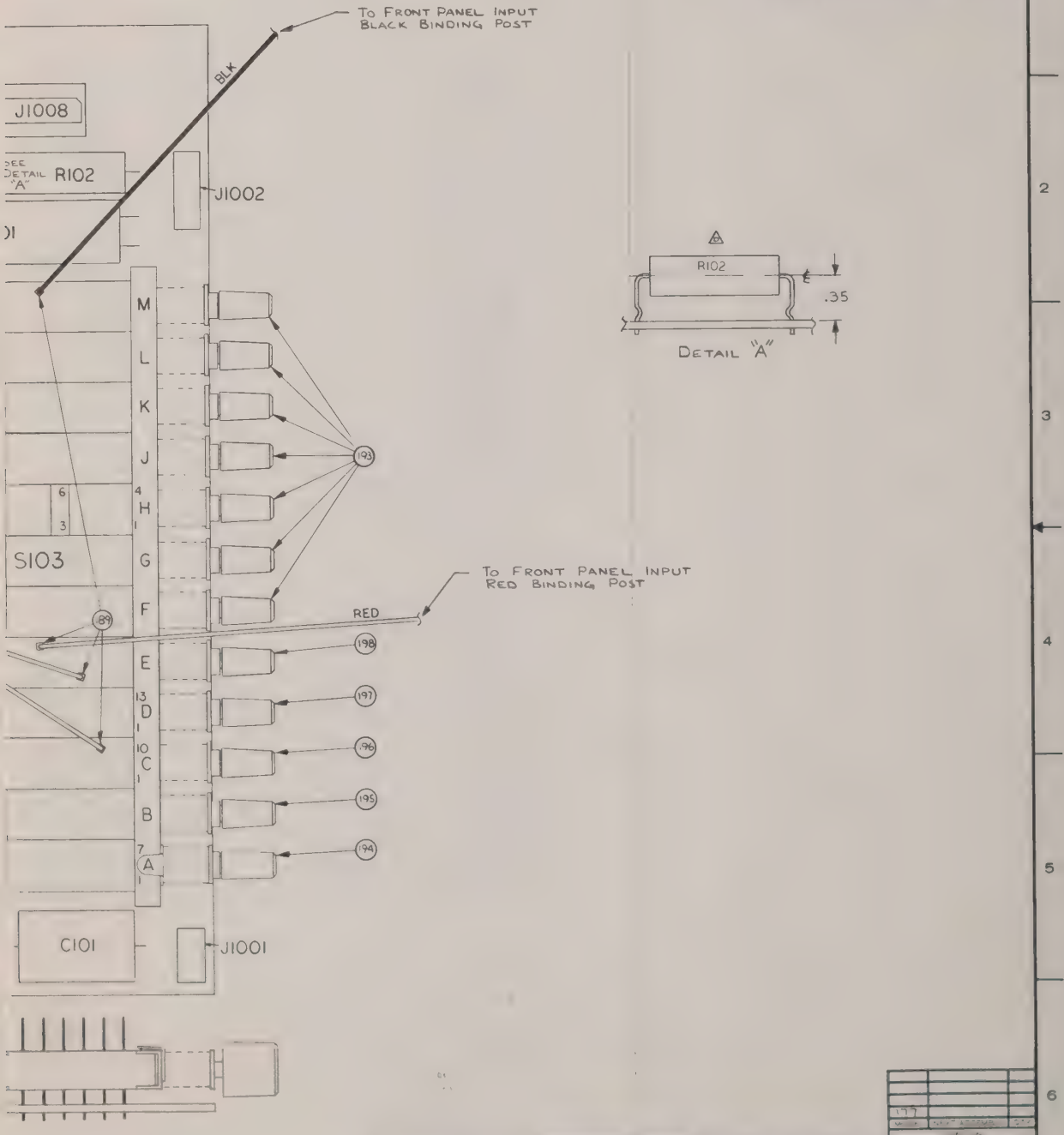
NO 290070


NOTES:
1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS, M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS.
3. ⊘ DENOTES INTERNAL ADJUST.
HIGHEST SCHEMATIC DESIGNATIONS USED
BT301 C305 CR303 F301
J1004 Q310 R316 T301
U302 VR301
SCHEMATIC DESIGNATIONS NOT USED
J1001 THRU J1003
SCHEMATIC BATTERY PACK
29659C
J1004
CLOCK
+5V
COMMON
+V
-V
F301 2A 3AG
BT301 8V 2.5AH
T301
Q301
Q302
Q303
Q304
Q305
Q306
Q307
Q308
Q309
Q310
U301
U302
CR301
CR302
CR303
CR304
CR305
VR301
R301 20K BAT. VOLT ADJ.
R302 330
R303 1K
R304 3.9
R305 4.7K
R306 3.3K
R307 82
R308 82
R309 10
R310 10
R311 100K
R312 100K
R313 100K
R314 6.8M
R315 576K
R316 100K
C301 4.7
C302 4.7
C303 1
C304 100
C305 100
KEITHLEY INSTRUMENTS CLEVELAND OHIO


PC-475
P1002
P1001
R201
R202
R203
C201
U202
U201
U203
DS201
DS202
DS203
DS204
DS205
3/8" INTERNAL TOOTH LOCKWASHER (2 REQ'D)
3/8" SMALL HEX NUT (2 REQ'D)
KEITHLEY INSTRUMENTS
DO NOT SCALE THIS DRAWING
COMPONENT LAYOUT, PC 475
ITEM | PART NO | SCHEM DESIG | ZONE
1 | 29437C | PC-475 | E2
2
3 | C179 4.7 | C201 | A3
4
5 | U201 | U201 | C2
6 | U202 | U202 | C2
7 | U203 | U203 | C2
8 | DS204 | DS204 | D2
9 | DS205 | DS205 | D2
10
ITEM | PART NO | SCHEM DESIG | ZONE
11 | CS-355-4 | P1001 | A3
12 | CS-355-6 | P1002 | F3
13
14 | TF-82 | R201 | E3
15 | TF-64 | R202 | E3
16 | RP-117-50K | R203 | A2
17
18 | IC-102 | U201 | E3
19 | IC-169 | U202 | E2
20 | IC-168 | U203 | E3


PC-476
#4-40 x 1/4" LG. PAN HEAD MACHINE SCREW & #4 KEP NUT
J1009
C115
C116
C117
U105
U106
R121
R122
R162
R159
R151
R150
R103
CR111
R136
CR110
U104
C132
U110
C130
U111
C118
U107
R165
CR112
CR113
Q106
Q107
R153
R152
R164
C111
R117
R119
C131
R118
C140
C135
R104
R105
Q105
C139
R125
C134
Q104
CR102
CR101
R130
R131
R132
R133
VR 104
R137
R135
P1004
R140
R141
Y101
R126
Q103
C124
C126
U108
C133
R144
R143
CR115
CR114
C138
U109
R134
R142
C120
CR117
R138
CR116
R148
C112
R156
R139
R154
YEL
ORN
F101
F102
S101
C123
CR120
R163
R146
R147
R157
R155
R149
R145
R114
R113
S102
P1003
Q102
C106
C107
R161
C109
C108
U102
R112
R111
R158
Q101
R109
C104
C103
U103
U101
R110
C105
R108
CR106
CR107
C102
R128
VR102
VR103
CR104
C122
C121
C125
VR101
K101
R107
T101
CR103
.112

ZONE	LTR	ECO NO	REVISION	DATE
	A	5941	RELEASED	4-1-78
E2	B	5952	ITEM 153 WAS R160	4-12-78
D3	C	5977	INTERCHANGED CR114 AND CR115	4-26-78
	D	6019	ADDED CR116 & CR117; DELETED ITEMS 153 & 192, DELETED NOTE ABOUT INSTALLING WASHER (ITEM 192) UNDER CLIP, ADDED DETAIL "A" CHANGED ARTWORK TO REV. D	6-9-78
E2	E	6068	ADDED J1008 ARTWORK WAS REV. D	7-24-78
	F	6126	ITEM 169 WAS IC-172	8-21-78



KEITHLEY INSTRUMENTS CLEVELAND OHIO	DATE 3 20 78	SCALE 2-1	TITLE COMPONENT LAYOUT, PC 476
	DRN R SMITH	ENG APPR R B	
	MATERIAL		SHEET 1 OF 2
	SURFACE MAX 63	FINISH	29474D

ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	29440D	PC-476	D1
2			
3			
4	C-285-.1	C101	E5
5	C-184	C102	C5
6	"	C103	C5
7	C-278-110pF	C104	C5
8	C-278-1100pF	C105	C5
9	C-228-33	C106	C4
10	"	C107	C4
11	C-294-1 OR C-296-1	C108	D4
12	"	C109	C4
13			
⚠ 14	C-22-2200pF	C111	C2
15	C-64-100pF	C112	C3
16			
17			
18	C-294-1 OR C-296-1	C115	B1
19	C-294-4	C116	B2
20	C-269-.22	C117	B2
21	C-294-.12	C118	C2
22			
23	C-290-2200	C120	B3
24	C-179-4.7	C121	B5
25	"	C122	B5
26	C-289-470	C123	B4
27	C-179-4.7	C124	C3
28	C-289-470	C125	B5
29	C-179-4.7	C126	C3
30			
31			
32			
33	C-64-100pF	C130	B2
34	C-252-100pF	C131	C2
35	"	C132	A2
36	C-301-.0047	C133	D3
37	C-294-.12	C134	D3
38	C-138-6800pF	C135	D3
39			
40			
41	C-294-2	C138	C3
42	C-294-1 OR C-296-1	C139	C3
43	C-301-.047	C140	D2
44			
45			
46	RF-48	CR101	D3
47	RF-34	CR102	D3
48	RF-36	CR103	B5
49	RF-46	CR104	B5
50			

ITEM	PART NO.	SCHEM DESIG	ZONE
51	RF-28	CR106	C5
52	"	CR107	C5
53			
54			
55	RF-28	CR110	A2
56	"	CR111	A2
57	"	CR112	B2
58	"	CR113	B2
59	"	CR114	D3
60	"	CR115	D3
⚠ 61	"	CR116	C3
⚠ 62	"	CR117	C3
63			
64			
65	RF-38	CR120	B4
66			
67			
68	FU-13	F101	D3
69	FU-20 *	F102	B4
70			
71	CS-356-4	J1001	E5
72	CS-356-6	J1002	E2
73	CS-288-3	P1003	A4
74	29467A	P1004	A3
75			
76			
77			
⚠ 78	SO-70	J1008	E2
79	29316A 2/u	J1009	A1, A2
80			
81			
82	RL-56	K101	C5
83			
84			
85	TG-77	Q101	C5
86	"	Q102	C4
87	TG-93	Q103	C3
88	TG-94	Q104	D3
89	TG-77	Q105	C3
90	TG-66	Q106	B2
91	TG-39	Q107	C2
92			
93			
94	R-262-.1	R101	E2
95	R-232-.898	R102	E2
96	R-252-9	R103	D2
97	R-169-90	R104	D2
98	R-168-900	R105	D2
99			
100	R-267-1M	R107	D5

ZONE	LTR	ECO NO	REVISION	DATE
	J	5941	RELEASED	4-3-78
	B	5952	[illegible]	[illegible]
	C	5977	[illegible]	4-26-78
	D	6019	[illegible] ADDED ITEM 62, 87, 88; DESIG CHGD DELETED ITEM 1, 2, 3 AND DELETED ITEM 192 WAS -71 ITEM 19 (CIR) WAS C-69-100pF	6-9-78
	E	6062	ADDED ITEM 78, 50-70 DESIG J008	7-24-78
	F	6126	ITEM #169 WAS IC-172	9-21-78

ITEM	PART NO.	SCHEM DESIG.	ZONE
101	R-176-990K	R108	C5
102	R-176-9.97K	R109	C5
103	R-176-991	R110	C5
104	R-176-90.3K	R111	C4
105	R-176-10K	R112	C4
106	RP-97-500	R113	D4
107	RP-97-50K	R114	D4
108			
109			
110	R-76-27K	R117	C2
⚠ 111	R-88-4.32K	R118	C3
112	R-88-4.99K	R119	C2
113			
114	R-1-3.9K	R121	A1
115	R-76-1K	R122	A1
116			
117			
118	TF-79	R125	C3
119	TF-80	R126	C3
120			
⚠ 121	R-76-27K	R128	D5
122			
123	R-88-649K	R130	A3
124	R-88-3.65K	R131	A3
125	R-88-806	R132	A3
126	R-263-2.15K	R133	A3
127	RP-64-50	R134	A3
128	R-263-402	R135	A3
129	R-88-100K	R136	B2
130	27699A	R137	A3
131	R-88-33.2K	R138	C4
132	RP-97-50K	R139	D3
133	R-76-47K	R140	B3
134	R-76-22M	R141	B3
⚠ 135	RP-64-1K	R142	A3
136	R-3-100K	R143	D3
137	R-76-22K	R144	D3
138	R-264-922	R145	C4
139	RP-97-10K	R146	C4
140	RP-97-100	R147	C4
141	R-263-8.95K	R148	C4
142	R-263-100	R149	C4
143	R-264-998K	R150	D2
144	"	R151	D2
145	"	R152	D2
146	R-264-994K	R153	D2
147	TF-78	R154	D3
148	RP-97-5K	R155	D4
149	RP-97-500	R156	D3
150	RP-97-50	R157	D4

ITEM	PART NO	SCHEM DESIG	ZONE
151	R-263-1.0K	R158	D4
152	RP-89-10K	R159	D2
⚠⚠ 153			
154	R-76-3.9M	R161	C4
155	RP-89-50K	R162	C2
156	RP-97-200K	R163	C4
⚠ 157	R-88-200K	R164	D2
⚠ 158	R-88-100	R165	C2
159			
160			
161	SW-318	S101	A4
162	SW-397	S102	B4
163	29434B	S103	E3-E5
164			
165	TR-168 *	T101	A5
166			
167	IC-196	U101	C5
168	IC-176	U102	C4
⚠ 169	IC-172-1 OR -2	U103	D5
170	IC-42	U104	A2
171	LSI-12	U105	A2
172	LSI-11-$\frac{3}{4}$ OR	U106	C2
173	IC-203	U107	C2
⚠ 174	IC-205	U108	C3
175	IC-203	U109	C3
176	IC-197	U110	B2
177	IC-139	U111	C2
178			
179			
180	IC-93	VR101	B5
181	IC-194 OR IC-34	VR102	B5
182	IC-195 OR IC-174	VR103	B5
183	27699A	VR104	A3
184			
185			
186	CR-8	Y101	B3
187			
188	FH-12 4/U	~	B4 D3
189	LU-90 4/U	~	E3, E4
190	MC-221	~	A5
191	28776A	~	C1
⚠ 192			
193	29465C-2 $\frac{3}{4}$U	S103F $\frac{3}{4}$M	F3
194	29465C-3 $\frac{1}{4}$U	S103A	F5
195	29465C-4 $\frac{1}{4}$U	S103B	F5
196	29465C-5 $\frac{1}{4}$U	S103C	F4
197	29465C-6 $\frac{1}{4}$U	S103D	F4
198	29465C-7 $\frac{1}{4}$U	S103E	F4
199			
200			

* NOTE:
FOR 100V JAPANESE VERSION SUSTITUTE
FU-29 FOR ITEM 69, FU-20 AND
TR-169 FOR ITEM 165, TR-168.

KEITHLEY INSTRUMENTS CLEVELAND OHIO

DRN R. SMITH

COMPONENT LAYOUT, PC-476

MATERIAL

SURFACE MAX 63

NO PAGE 2 of 2

29474D

KEITHLEY INSTRUMENTS, INC.
28775 AURORA ROAD
CLEVELAND, OHIO 44139

SERVICE FORM

MODEL NO._____ SERIAL NO._____ P.O. NO._____ DATE_____ R-

NAME _____ PHONE _____

COMPANY _____

ADDRESS _____ CITY _____ STATE _____ ZIP _____

1. Describe problem and symptoms using quantitative data whenever possible (enclose readings, chart recordings, etc.) _____

_____

_____ (Attach additional sheets as necessary).

2. Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

3. List the positions of all controls and switches on both front and rear panels of the instrument. _____

_____

4. Describe input signal source levels, frequencies, etc. _____

_____

_____

5. List and describe all cables used in the experiment (length, shielding, etc.).

_____

_____

6. List and describe all other equipment used in the experiment. Give control settings for each. _____

_____

_____

7. Environment:
   Where is the measurement being performed? (Factory, controlled laboratory, out-of-doors, etc.) _____
   What power line voltage is used? _____ Variation? _____ Frequency? _____
   Ambient temperature? _____°F. Variation? _____°F. Rel. Humidity? _____
   Other _____

8. Additional Information. (If special modifications have been made by the user, please describe below.) _____

_____

KEITHLEY

Keithley Instruments, Inc./28775 Aurora Road/Cleveland, Ohio 44139/(216) 248-0400/Telex: 98-5469

Keithley Instruments GmbH/Heiglhofstrasse 5/D-8000 Munchen 70/(089) 714-40-65/Telex: 521 21 60

Keithley Instruments, Ltd./1, Boulton Road/GB-Reading, Berkshire RG2 ONL/(0734) 86 12 87

Keithley Instruments SARL/44, Rue Anatole France/F-91121 Palaiseau Cedex/01-014-22-06/Telex: (842) 204188